



**Erosion Assessment and Erosion Prevention
Planning Project for Forest Roads
in the Biscuit Fire Area, Southern Oregon**

prepared for

**Pacific Rivers Council
and
The Siskiyou Project**

by

**Pacific Watershed Associates
Arcata, California
(707) 839-5130
April, 2005**

Erosion Assessment and Erosion Prevention Planning Project for Forest Roads in the Biscuit Fire Area, Southern Oregon

Table of Contents

	<u>Page</u>
<i>Executive Summary</i>	1
<i>I. Background</i>	3
<i>II. Project Description</i>	4
<i>III. Forward-looking Sediment Source Inventories</i>	6
<i>IV. Inventory Results</i>	7
<i>V. Restoration Treatments</i>	13
<i>VI. Restoration Costs</i>	18
<i>VI. Conclusions</i>	19
<i>VII. References</i>	21
 <u>Appendices</u>	
<i>Appendix 1 (Summary Assessment Results for Six Planning Watersheds)</i>	25
<i>Appendix 2a - 2f (Sites of future road-related erosion and sediment delivery)</i>	30
<i>Appendix 3a - 3f (Site specific treatment priorities for all inventoried sediment sources)</i> ...	37
<i>Appendix 4a - 4f (Recommended treatments along all inventoried roads)</i>	45
<i>Appendix 5 (Preliminary, Phase 1 Restoration Cost Estimate)</i>	53
 <u>List of Maps</u>	
<i>1. Biscuit Fire Restoration Area Composite Map of Identified Roads</i>	<i>in back of report</i>
<i>2. Biscuit Fire Restoration Area Composite Map of Inventoried Roads</i>	<i>in back of report</i>
<i>3. Sites of Future Sediment Delivery by Problem Type,</i> <i>Indigo Creek Planning Watershed</i>	<i>in back of report</i>
<i>4. Sites of Future Sediment Delivery by Treatment Immediacy,</i> <i>Indigo Creek Planning Watershed</i>	<i>in back of report</i>
<i>5. Enlarged Map Showing Sites of Future Sediment Delivery by Problem Type</i> <i>and Treatment Immediacy, Indigo Creek Planning Watershed</i>	<i>in back of report</i>



Erosion Assessment and Erosion Prevention Planning Project for Forest Roads in the Biscuit Fire Area, Southern Oregon

prepared by
Pacific Watershed Associates

for
**Pacific Rivers Council
and The Siskiyou Project**

Executive Summary

We conducted a rapid “forward-looking” erosion assessment of representative forest roads in the Biscuit Fire area, southern Oregon, to identify the nature and magnitude of expected post-fire road-related sediment delivery. A stratified sample of 135 miles of roads in six of the area’s planning watersheds were inventoried for current and future sediment sources that could impact streams. In the assessment we inventoried only those sites and road reaches where eroded sediment would be delivered to a stream channel. The data provides quantitative estimates, or ranges, of how much sediment could be eroded and delivered in the future from these sites, if no erosion control or erosion prevention work is performed. Finally, we identified potential treatment opportunities, prioritized treatment sites and developed a cost estimate for the recommended erosion prevention and sediment control work.

The primary purpose of the watershed assessment project was to identify, prioritize and prescribe treatments for existing and potential sediment sources on streamside (lower slope), mid-slope and ridge top roads located in key watersheds. The analysis consisted of four core elements: 1) an air photo analysis of roads (to determine the extent of the road network), 2) a rapid field inventory of a stratified sample of representative roads to identify future sites of sediment delivery, 3) preparation of an erosion control and erosion prevention plan for the sampled roads, and 4) developing a cost estimate for implementing the sediment reduction measures on these and other roads within the Biscuit Fire area.

Air photo analysis - Roads have long been recognized as an important and often leading source of anthropogenic sediment in forested, managed watersheds of the Pacific Northwest. In the air photo analysis of the entire southern Oregon portion of Biscuit Fire area, using pre- and post-fire orthophotos, we identified nearly 730 miles of forest roads; approximately 30% more roads than were identified on transportation maps and digital map data supplied by the US Forest Service. Some of the roads not depicted on USFS road maps are abandoned and at least partially overgrown. Field sampling suggests that most closed or abandoned roads have not been properly decommissioned to eliminate the potential for continuing or future erosion and sediment delivery to streams.

Road sediment sources - In our sample inventory, we mapped an average six (6) sediment delivery sites per mile of inventoried road. Road-related erosion and sediment delivery is expected to come from three sources: 1) erosion at, or associated with, stream crossings, 2) fillslope landslides, and 3) road surface drainage. Each site with delivery potential was categorized according to erosion potential (the likelihood of erosion), expected volume of erosion and sediment delivery, and various treatment options designed to reduce or eliminate future sediment delivery.

Stream crossing erosion - A total of 572 stream crossing sites (4 crossings/mile of inventoried road) were identified as existing or potential road-related erosion sources that could deliver sediment to streams. The most common stream crossing problems included undersized culverts (culverts not designed for 100-year flows), worn out culverts (bottom rusted through) and crossings with a diversion potential. Over 300 culverted stream crossings are currently undersized or worn out. A total of 385 stream crossings currently have a diversion potential, including 59 that are now diverted down the ditch. Finally, 146 of the inventoried stream crossings have a moderate or high potential to plug with sediment or organic debris. The most significant threats of sediment delivery come from stream crossings whose culverts are undersized or have a high plug potential, and also exhibit a potential for stream diversion.

A total of 255,000 cubic yards of eroded sediment could be delivered from stream crossings if they were to fail. Although not all are expected to simultaneously fail, each of the 572 inventoried stream crossings have been evaluated for their failure potential and expected sediment delivery volume. Those sites categorized as having a high or moderate-high treatment immediacy (priority) should be treated soon, before they fail. The most commonly recommended treatments include replacing undersized and worn out culverts with culverts designed to pass 100-year flood flows (including organic debris) and constructing critical dips to eliminate the potential for future stream diversion. A critical dip is a broad rolling dip or low point constructed in the roadbed at the crossing to prevent flood flows from diverting or flowing down the adjacent road or ditch when the culvert plugs.

Road-related landslides - A total of 52 potential fillslope failures that could deliver sediment to local streams were identified along the 135 miles of inventoried road (0.4 potential landslides/mile). Only potential landslides exhibiting physical signs of pending failure and the potential to deliver sediment to a stream were inventoried. Unless treated, these 52 landslides are expected to deliver 20,800 cubic yards of sediment to stream channels when they fail. The most common treatment for potential fillslope landslides is to excavate the unstable material and endhaul the spoil to a stable disposal site.

Chronic road surface erosion - Perhaps the most insidious source of sediment from road systems in the Biscuit Fire area is surface erosion and fine sediment delivery from road surface runoff and road drainage. Road surface erosion is a chronic source of sediment supply to streams in all the affected watersheds, and it occurs wherever roads are drained to stream channels through ditches or other drainage features. It occurs not just during large storms, but every time there is surface runoff from the roads and ditches. In addition, where roads are insloped or bermed, road drainage released on steep hillslopes causes gullying and sediment delivery (e.g., gullying below ditch culverts). Although some roads are properly outsloped, 55% (72.5 miles) of the inventoried road network is now “hydrologically connected” and currently delivering road runoff and eroded fine sediment to streams.

Over the next decade, unless road surface drainage treatments are applied, we estimate that over 102,000 yd³ of fine sediment will be delivered to the stream system from these “connected” road reaches, thereby continuing to degrade downstream salmonid spawning and rearing habitat. Proposed treatments are straightforward and consist of installing road drainage measures that disperse runoff and “disconnect” the road drainage system from the natural stream channel network. We have identified specific locations along the 135 miles of inventoried road where sediment delivery can be dramatically reduced by simple road shaping measures and by the installation of drainage structures, including 1,460 rolling dips and 450 ditch relief culverts.

Recommended treatment strategy - Recommended erosion prevention work includes upgrading a number of existing roads located in stable locations and decommissioning abandoned and high risk roads that exhibit significant potential for future sediment delivery. Based on the 135 miles of inventoried road in this reconnaissance inventory, 753 treatment sites have been prioritized for erosion prevention or erosion

control treatments. All roads proposed for prioritized treatment currently threaten to deliver sediment to the key watersheds if they are left untreated. Altogether, 173 sites (22%) are identified as having a high or moderate-high treatment immediacy (priority). These sites have the highest overall priority for erosion prevention or erosion control treatment, and should be the focus of the immediate restoration efforts.

Inventory results from the 135 mile sample road assessment conducted in six planning watersheds have been extrapolated to the full 728 mile road system in the Biscuit Fire area to develop a preliminary planning-level estimate for expected restoration costs. Estimated road treatment costs for all sites and delivering road reaches range from \$27.5 to \$40 million for all 728 miles of roads in the Biscuit Fire area. Estimated costs include full assessment and site planning, prescription development, on-the-ground implementation using heavy equipment and labor crews working at federal “prevailing wage rates,” as well as project oversight, contracting, administration and associated overhead.

Background

Researchers have found that most native salmonid species are adapted to natural patterns and processes of disturbance and recovery in the landscape and that preventing additional human disturbance (and reducing the effects of past disturbance) will generally provide the best management strategy for regional ecological recovery (Beschta, et al., 2004; Beschta et al, 1995). Watershed scientists have identified excess sediment production and delivery to stream channels from active and abandoned road systems as one of the most significant, and perhaps the most easily controlled, factors affecting the reproductive success and survival of salmonid populations (Furniss et al, 1991; Furniss et al, 2000; Harr and Nichols, 1993; CDFG, 2004; Luce et al, 2001). Perhaps the most important element needed for the protection and long term restoration of salmon habitat, and the eventual recovery salmonid populations in watersheds of the Biscuit Fire area, is the reduction of accelerated erosion and sediment delivery from lands affected by the Biscuit Fire. Techniques for performing watershed-scale forward-looking erosion assessments, and subsequently developing prioritized, cost-effective restoration programs for controlling road related erosion and sediment delivery, have been in practice for several decades (Harr and Nichols 1993; CDFG 2003; Burroughs and King, 1989; Weaver and Hagans; 1994; Weaver and Hagans, 1999).

This rapid assessment project consisted of a field inventory of selected forest roads within the Biscuit Fire area, as well as several main-line haul roads leading from adjacent unburned lands from the fire area, to identify existing and potential road-related sediment sources (Map 1). Within this area, a limited sample of typical forest roads, in various geomorphic and physiographic settings, were selected for evaluation and analysis. Field work was conducted over three weeks in June, September and October, 2004. At sites of future erosion and sediment delivery, generalized treatment prescriptions were developed for cost-effective erosion prevention and erosion control. The proposed erosion prevention and erosion control work calls for road upgrading (storm-proofing) of roads that are a part of the active transportation system, and decommissioning of roads that are already in an abandoned, unmaintained status (Weaver and Hagans, 1999). The proposed treatments have been prioritized based on the sensitivity of the fisheries, the potential for sediment delivery, the volume of expected sediment delivery and treatment cost-effectiveness (Weaver and Sonnevil, 1984; Weaver and Hagans, 2004).

Erosion prevention and sediment control measures for road-related sediment sources address keystone problems related to issues of water quality, spawning requirements and rearing habitat. A framework assessment and plan for a portion of roads inventoried in six of the eleven key watersheds has been prepared for road-related erosion prevention and erosion control work (Table 1). The eleven key watersheds in the Biscuit Fire area are underlain by highly erodible and locally unstable geologic substrate, and both field observations and analysis of aerial photographs suggest that roads have been a significant source of accelerated sediment production. Now that the area has been burned, sediment production from roads is likely to increase.

This summary report describes the aerial photo analysis, reconnaissance watershed assessment and inventory process, and the proposed treatment plan for the inventoried roads. It serves as a prioritized general plan-of-action for cost-effective erosion control and erosion prevention treatments for inventoried portions of the Biscuit Fire area. When erosion control treatments are implemented in combination with protective land use practices, the proposed projects will contribute to the long-term protection and improvement of water quality and salmonid habitat. The implementation of erosion control and erosion prevention work is an important step towards protecting and restoring watersheds and their anadromous fisheries (especially where sediment input is a limiting or potentially limiting factor to fisheries production, as is thought to be the case for many of Oregon's coastal streams and the Illinois River Basin).

Unlike many watershed improvement and restoration activities, erosion prevention and "storm-proofing" of forest road systems has an immediate benefit to the stream's water quality and aquatic habitat of the basin. It helps ensure that the biological productivity of the watershed's streams is not impacted by future human-caused erosion, and that future storm runoff can cleanse the streams of accumulated coarse and fine sediment, rather than depositing additional sediment from managed areas. Sites targeted for immediate implementation in the project area have been identified as priority sites for treatment so that fill failures, stream crossing wash-outs and stream diversions do not continue to degrade the key watersheds of the Southern Oregon project area.

The first phase of the sediment source inventory and reconnaissance for the Biscuit Fire area, funded by PRC, has recently been completed. Among other things, this assessment identified many recognizable current and future sediment sources in six key watersheds on streamside, mid-slope, and ridge top roads. The primary objective of the project was to identify, prioritize and implement cost-effective erosion control and erosion prevention work on priority sites that are identified as a part of this inventory.

Project Description

Part 1 - Air Photo Analysis

In the first phase of the Watershed Assessment and Erosion Prevention Planning Project for the Biscuit Fire area, all mapped roads within the study area were identified using multiple public maps and GIS data files obtained through a USFS Freedom of Information Act (FOIA) request. As is frequently the case, not all the roads that occur in the watersheds are depicted on the available maps. Some are not shown, and others that are not shown have been abandoned and

are in disrepair. The older, unmaintained roads are often not shown on maps, but they exist on the landscape and they may represent potentially significant future sediment sources.

Digital orthophotoquads obtained by the USFS FOIA were analyzed to map the location of unmapped roads (roads not shown on USFS compiled maps). Two different photo periods were sequentially reviewed to identify all the roads within the Biscuit Fire area. A base map consisting of USFS mapped roads and additional roads independently mapped by Pacific Watershed Associates (PWA) geologists and hydrologists PWA was prepared. The base map was later updated during field inventories, and a final base map was prepared that depicts the entire road network in the Biscuit Fire area (Map 1). During the field assessment, as they were encountered, the unmapped roads (those not shown on USFS road maps) were identified and classified as abandoned and/or closed.¹

Part 2 - Field Inventory of Roads

The second phase of the project involved a field inventory of selected road systems identified from the analysis of aerial photos and compilation of existing road maps and digital map data. Because not all roads could be inventoried in this rapid reconnaissance assessment, a sample of ridge top, mid-slope and lower slope roads were inventoried in a number of watersheds. Technically, this field assessment was neither an erosion inventory nor a road maintenance inventory. Rather, it was a forward-looking inventory of sites where there is a potential for future sediment delivery to the stream system that could impact fish bearing streams in the watershed (CDFG, 2004).

All prioritized streamside, mid-slope and ridge top roads, including maintained, closed, tank-trapped, decommissioned and abandoned routes, were walked and inspected by trained personnel and all existing and potential sediment delivery sites were identified in the field. Sites, as defined in this assessment, include locations where there is direct evidence that future erosion or mass wasting could be expected to deliver sediment to a stream channel. Sites of past road-related erosion were not inventoried unless there was a potential for additional future sediment delivery. Similarly, sites of future erosion that are not expected to deliver sediment to a stream channel were not included in the inventory.

Inventoried sites of existing and future sediment delivery generally consisted of stream crossings, potential and existing landslides related to the road system, gullies below ditch relief culverts and long sections of uncontrolled road surface and ditch runoff that currently discharge fine sediment to the stream system. For each existing or potential erosion source that was identified, a database form was filled out and the site was mapped on a mylar overlay over a 1:12,000 scale topographic map. The database field form contained questions regarding the site location, culvert condition, the nature and magnitude of existing and potential erosion problems, the likelihood of post-fire erosion or slope failure, the expected volume of erosion and sediment

¹ Unmapped abandoned and closed roads were not simply gated. Most had obstructions at their beginning, including deep trenches or large logs, to prevent vehicle access. Many of these roads have been closed for a number of years and are partially or completely overgrown with vegetation. The drainage structures (culverts) are no longer being maintained. Few of these roads have been proactively or properly decommissioned, as defined in the Northwest Forest Plan.

delivery, and recommended treatments to eliminate or reduce future sediment delivery from the site or road reach.

Forward-looking Sediment Source Inventory and Erosion Prevention Planning

The forward-looking sediment source inventory is designed to provide information that can be used to identify and prioritize erosion prevention, erosion control and road decommissioning activities in a watershed (CDFG, 2004). Not all of the sites that have been recommended for treatment have the same priority, and some can be treated more cost effectively than others (Weaver and Sonnevil, 1984). Treatment priorities are evaluated on the basis of several factors and conditions associated with each potential erosion site:

- 1) the expected volume and rate of sediment to be delivered to streams (yds³);
- 2) the potential or “likelihood” of future erosion (erosion potential - high, moderate, low);
- 3) the “urgency” of treating the site (treatment immediacy - high, moderate, low);
- 4) the ease and cost of accessing the site for treatments; and
- 5) recommended treatments, logistics and costs.

The *erosion potential* of a site is a professional evaluation of the likelihood that erosion will occur during a future storm event. Erosion potential is an estimate of the potential for additional erosion, based on field observations of a number of local site conditions. Erosion potential is evaluated for each site, and expressed as “High,” “Moderate” or “Low.” The evaluation of erosion potential is a subjective estimate of the probability of erosion, and not an estimate of how much erosion is likely to occur. It is based on the age and nature of direct physical indicators and evidence of pending instability or erosion. The likelihood of erosion (erosion potential) and the volume of sediment expected to enter a stream channel from future erosion (sediment delivery) play significant roles in determining the treatment priority of each inventoried site (see “treatment immediacy,” below). Field indicators that are evaluated in determining the potential for sediment delivery include such factors as slope steepness, slope shape, distance to the stream channel, soil moisture and evaluation of erosion process. The quicker the rate and larger the potential future contribution of sediment to a stream, the more important it becomes to closely evaluate its potential for cost-effective treatment.

Treatment immediacy (treatment priority) is a professional evaluation of how important it is to “quickly” perform erosion control or erosion prevention work. It is also categorized as either “High”, “Moderate”, or “Low” and represents both the severity of the problem and urgency of addressing the threat of sediment delivery to downstream salmonid habitat. An evaluation of treatment immediacy considers erosion potential, future erosion and sediment delivery volumes, the rate of erosion, the value or sensitivity of downstream resources being protected, and treatability, as well as, in some cases, whether or not there is potential for an extremely large erosion event occurring at the site (larger than field evidence might at first suggest). If mass wasting, culvert failure or sediment delivery is imminent, even in an average winter, then treatment immediacy might be judged “High”. Treatment immediacy is a summary, professional assessment of a site’s need for immediate treatment. Generally, sites that are likely to erode or

fail in a normal winter, and that are expected to deliver significant quantities of sediment to a stream channel, are rated as having a high treatment immediacy or priority.

One other factor influencing a site's treatment priority is the difficulty (cost and environmental impact) of reaching the site with the necessary equipment to effectively treat the potential erosion (Weaver and Hagans, 2004; CDFG 2004). Many sites found on abandoned or unmaintained roads require brushing and tree removal to provide access to the site(s). Abandoned roads may require minor road rebuilding of washed-out stream crossings and/or existing landslides in order to reach potential work sites farther out the alignment. Road reconstruction adds to the overall cost of erosion control work and reduces project cost-effectiveness (Weaver and Hagans, 2004). Potential work sites with lower cost-effectiveness, in turn may be of relatively lower priority. However, just because a road is abandoned and/or overgrown with vegetation is not sufficient reason to discount its need for assessment and potential treatment. Treatments on heavily overgrown, abandoned roads may still be both beneficial and cost-effective.

Inventory Results

The primary emphasis of the Watershed Assessment and Erosion Prevention Planning Project was to identify, prioritize and prescribe treatments for existing and potential sediment sources identified on over 135 miles of streamside (lower slope), mid-slope and ridge top roads located in the key watersheds within the Biscuit Fire area. In the six key watersheds, the field inventory crews identified future sediment sources from 797 sites, of which 753 sites are recommended for treatment on approximately 135 miles of recreation, mining, and logging roads in the Biscuit Fire area (Table 1; Maps 1 and 2).

In addition, many of these roads are well integrated with the natural stream network; delivering fine sediment eroded from the road surface directly into adjacent watercourses.

Roads in the Biscuit Fire area
Approximately 30% of the roads in the Biscuit Fire watersheds are not shown on available USFS maps and

digital map files. Map 1 and Table 2 differentiate the roads identified and mapped by the USFS (as contained on publically available maps and electronic USFS GIS data files) from the additional roads identified by PWA through either air photo analysis or field inspection of the same areas. Analysis of pre-fire imagery from 1996 and post-fire imagery from 2003 revealed the presence of an additional 221 miles of road that are not shown on USFS maps and data files (Table 2).

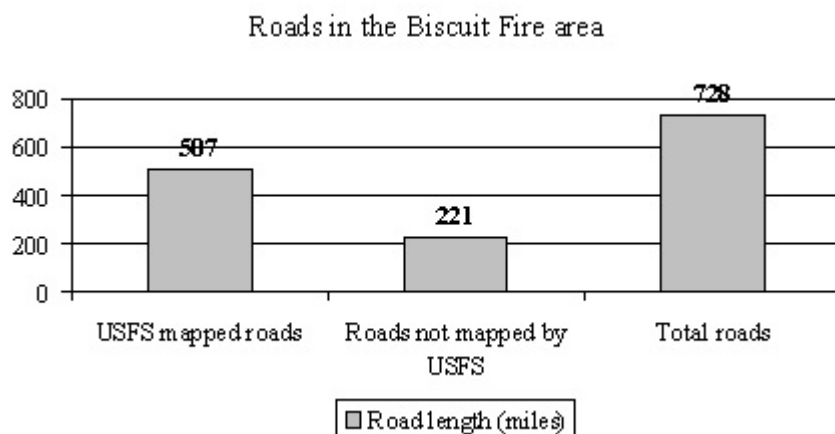


Table 1. Total inventoried road miles and sites of future sediment delivery and potential treatment, by watershed, for the Biscuit Fire Restoration Project, Southern Oregon.

Inventoried Watersheds	Inventoried miles of road	Connected miles of road ¹	Inventoried sites (#)	Sites recommended for treatment (#) ²	Problem type		
					Stream crossings	Slides	Other ³
Chetco River	23.4	20.0	174	164	147	8	19
Illinois River/ Josephine Creek	15.6	15.0	162	150	99	1	62
Indigo Creek	48.5	19.9	241	238	172	16	53
Lawson Creek	19.8	9.4	126	114	89	12	25
Pistol Creek	2.9	2.9	27	27	23	0	4
Silver Creek	25.3	5.4	67	60	42	6	19
Illinois River/ Klondike Creek	0	N/A	N/A	N/A	N/A	N/A	N/A
North Fork Smith River	0	N/A	N/A	N/A	N/A	N/A	N/A
West Fork Illinois	0	N/A	N/A	N/A	N/A	N/A	N/A
Deer Creek	0	N/A	N/A	N/A	N/A	N/A	N/A
Biggs Creek	0	N/A	N/A	N/A	N/A	N/A	N/A
Totals	135.5	72.5	797	753	572	43	182

¹ Miles of “hydrologically connected” road lengths and/or ditch lengths that chronically deliver runoff and fine sediment from the eroding road surface, ditch and cutbanks to the natural stream network.

² Treat sites are recommended for erosion control work to prevent future episodic erosion and sediment delivery from stream crossing failures and potential landslides. Treatments are also prescribed for reducing road-stream connectivity and the delivery of fine sediment from roads and cutbanks.

³ Problem sites identified as “Other” typically include road surface drainage problems; gullies, ditch relief culverts and springs.

⁴ The Upper Chetco and Chetco River planning watersheds road miles are combined. In the Chetco River watershed we inventoried 13.48 miles of main line appurtenant haul road outside the Biscuit Fire area.

Table 2. Road miles identified and/or inventoried by the USFS (maps and GIS) and PWA (air photo analysis), by key watershed in the Biscuit Fire Area, Southern Oregon

Key Watersheds	USFS-Identified Miles of Road	Additional Road Miles Identified by PWA on Digital Orthophotoquads	Grand Total Miles of Road in the Biscuit Fire Area	Closed, Tank-trapped or Abandoned Roads Identified by PWA Field Inventories (mi) ³	PWA Inventoried Miles
Chetco River ¹	66.3	26.8	93.1	0	23.4
Illinois River/ Josephine Creek	92.3	48.3	140.6	0.3	15.6
Indigo Creek	92.8	14.7	107.5	10.0	48.0
Lawson Creek	61.8	24.3	86.1	6.9	19.8
Pistol Creek	21.1	8.9	30.0	0	2.9
Silver Creek	84.8	57.3	142.1	1.8	25.3
Illinois River/ Klondike Creek	22.1	5.1	27.2	3.8	0
North Fork Smith River ²	27.0	5.8	32.8	0	0
West Fork Illinois	21.4	13.9	35.3	0	0
Deer Creek	2.8	10.2	13.0	0	0
Biggs Creek	14.6	6.0	20.6	0	0
Totals	507	221.3	728	22.8	135.5

¹ The Upper Chetco and Chetco River planning watersheds road miles are combined. In the Chetco River watershed we inventoried 16.8 miles of haul road outside the Biscuit Fire area.

² Only roads in Oregon are identified in this project, California is not included.

³ This is a limited sample comprised only of roads noted by PWA personnel during the field inventory.

Nearly 221 additional miles of streamside, mid-slope, and ridge top roads were identified during our analysis of orthophotoquads, for a total of 728 miles of road in the assessment area (Map 1). Of this, only a small portion (18%) of the total road miles in the Biscuit Fire area were inventoried by PWA’s technical staff in six of the eleven key watersheds. In our sample inventory, we mapped an average 6.0 sediment delivery sites per mile of inventoried road. During the field survey we identified a sample of 22.8 miles of closed and tank-trapped roads that appear to have been improperly decommissioned and have not been “storm-proofed” (Table 2)(USDA, 1993; Weaver and Hagans, 1999; CDFG, 2004). Finally, 13.5 miles of logging haul routes outside the delineated Biscuit Fire area were also included in the inventory. These included streamside roads that parallel Southern Oregon’s Wild and Scenic Rivers and are ultimately a link to the management of the forest. Because they serve as potential appurtenant main line haul roads, they were also sampled as a part of this reconnaissance erosion prevention planning project.

Sources of Sediment Delivery

The great majority of future road-related erosion and sediment delivery in the project area is expected to come from three sediment sources: 1) erosion at or associated with stream crossings (from several possible causes), 2) the failure of road and landing fillslopes (landsliding), and 3) road surface drainage problems (road surface, ditch and gully erosion) associated with hydrologic connectivity between road drainage and the with the natural stream channel network (Wemple, et al., 1996). A total of 572 stream crossing sites and 52 potential fillslope failures are identified as existing or potential road-related erosion sources that could deliver sediment to streams. Potential fillslope failures were

identified on steep slopes where landing fillslopes and roadbed side cast showed signs of potential failure and sediment delivery.

The data provides quantitative estimates, or ranges, of how much material could be eroded and delivered in the future from specific sites, if no erosion control or erosion prevention work is performed.

In a number of locations, especially at stream diversion sites, actual sediment loss could easily exceed field predictions. At the same time, not all sites have the same potential for failure, and not all sites will fail. For this reason, the erosion potential (and potential for sediment delivery) was estimated for each major problem site or potential problem site on the inventoried roads. All sites are assigned a treatment priority (Treatment Immediacy), based on their potential to deliver sediment to stream channels in the watershed and the cost-effectiveness of the proposed treatments (Table 3).

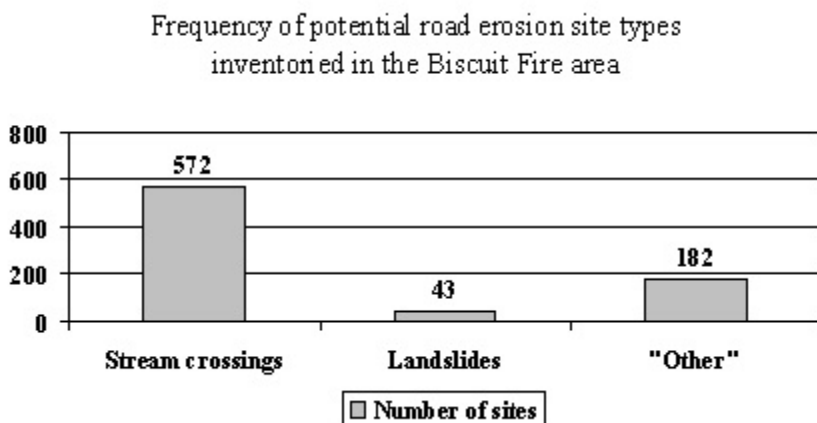


Table 3. Inventoried sites, treatment priorities (Treatment Immediacy) and potential episodic sediment delivery classes for planning watersheds in the Biscuit Fire Area (PRC/PWA, 2004)

Inventoried Watershed	Inventoried sites (#)	Treatment Immediacy (H, HM, M, ML, L) ¹				Estimated volume of all 797 inventoried sites (potential sediment delivery volume) ²				
		H;HM	M;ML	L	NO	S	M	L	XL	XXL
Chetco River	174	46	71	51	20	93	54	24	10	7
Illinois River/ Josephine Creek	162	14	101	54	14	124	40	8	8	3
Indigo Creek	241	52	122	62	5	108	100	21	11	1
Lawson Creek	126	46	34	11	0	63	20	6	2	0
Pistol Creek	27	11	15	1	0	15	9	3	0	0
Silver Creek	67	4	28	28	7	49	16	2	0	0
Totals	797	173	371	207	46	452	239	64	31	11

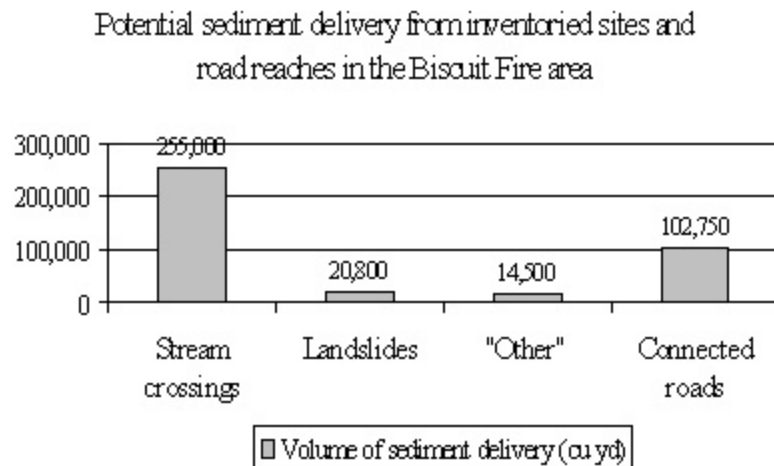
¹ Treatment priority: H = High; HM = High-Moderate; M = Moderate; ML = Moderate-Low; L = Low, NO = No treat.
² Volume size classes (cubic yards): Small (S) = 0-100; Medium (M) = 100-500; Large (L) = 500-1,000; XL = 1,000-5,000; XXL = >5,000.

Table 4. Potential episodic sediment delivery volumes for inventoried sites on USFS roads in the Biscuit Fire Area (PRC/PWA, 2004)

Inventoried Watershed	Estimated sediment delivery volume of inventoried sites (potential sediment delivery volume) ¹				
	S (50)	M (300)	L (750)	XL (3000)	XXL (5000)
Chetco River	4,650	16,200	18,000	30,000	35,000
Illinois River/ Josephine Creek	6,200	12,000	6,000	24,000	15,000
Indigo Creek	5,400	30,000	15,750	33,000	5,000
Lawson Creek	3,150	6,000	4,500	6,000	0
Pistol Creek	750	2,700	2,250	0	0
Silver Creek	2,450	4,800	1,500	0	0
Total Number	452	239	64	31	11
Total Yield	22,600	71,700	48,000	93,000	55,000

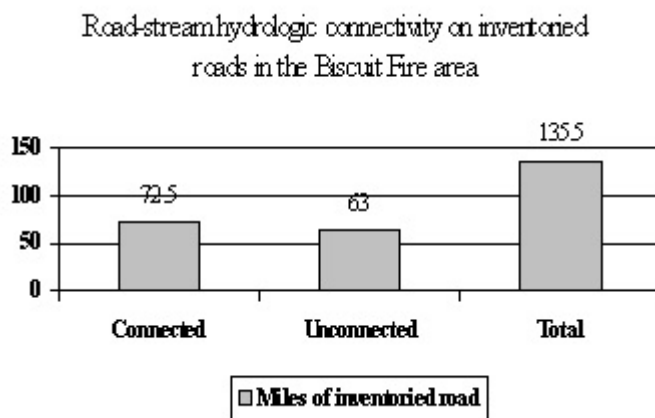
¹ Volume size classes (cubic yards): Small (S) = 0-100; Medium (M) = 100-500; Large (L) = 500-1,000; XL = 1,000-5,000; XXL = >5,000.

During the field inventory, sites of future erosion and sediment delivery were broadly categorized into volume, or yield, classes. The number of sites within each yield class, as well as the number of sites within each treatment priority category, are depicted in Table 3. The data shows that erosion sites in the small volume class are relatively numerous compared to those in increasingly larger volume classes (Table 3). To convert the volume classes of Table 3 to sediment delivery volumes we multiplied the number of sites within each class (Table 3) by the mean value for that volume class. For example, for the “medium” volume class (100 - 500 cu yd of potential sediment delivery) we assigned an average yield of 300 cubic yards. The 239 inventoried sites within this size class have the potential to generate (deliver) a total of 71,700 cu yd, if and when they fail or erode. The values for sediment delivery from sites recommended for treatment are shown in Table 4.



The largest volume classes (XL and XXL) are typically large landslides and very large stream crossing fills that have a potential to fail. The methodology of employing volume range classes rather than conducting more rigorous volume surveys of each site results in a more extensive survey of roads while still providing order-of-magnitude estimates of volumes needed to assess the establish treatment priorities. Actual site treatments, if and when conducted, would require more definitive volume measurements at each proposed work site.

In addition to feeding road surface, cutbank and ditch sediment to the stream network, hydrologic connectivity between the road network and the stream network can also alter stream hydrographs, downstream flooding, and the production and movement of sediment in channel systems (Wemple and Jones, 2003). Treatments along unstable and/or high yield roads or road reaches can be accomplished by permanently decommissioning (closing) or “storm proofing” (upgrading) the sites identified on the site location map (Table 1 and Map 1). Although some roads are properly outsloped, 55%, or 72.5 miles, of the inventoried road network is at least partially “hydrologically connected” to streams and currently delivering fine



sediments to streams and stream crossings. Road surface, ditch and cutbank lowering rates can be rapid, depending on soil erodibility and traffic levels (Reid and Dunne, 1984)).

Chronic surface erosion and ditch runoff delivers fine sediment annually with every storm to the stream crossings (Table 1 and Appendix 2a - 2f). The total potential sediment delivery from the inventoried roads includes sediment from inventoried sites that fail episodically during storm events, as well as fine sediment derived from, and delivered through, hydrologically connected road surfaces and ditches.

Restoration Treatments

Land and resource stewardship dictates that roads be either upgraded and maintained, or properly decommissioned so they are no longer a threat to water quality and aquatic habitat (Furniss et al., 1991; Luce et al., 2001; Weaver and Hagans, 1994; Weaver and Hagans, 1999; CDFG 2004). It is no longer acceptable to ignore maintenance and erosion prevention needs, or to abandon roads that have potential sediment sources along their alignments (USDA, 1993; CDFG, 2004). Roads have been identified as the most common and important human-caused sources of sediment in managed watersheds (Beschta, 1995; Harr and Nichols, 1993; USDA, 1993; Weaver et al., 1995; Wemple et al., 2001). Fortunately, roads are also one of the most easily treated anthropogenic sediment sources (Weaver and Hagans, 1996). Roads are considered “storm-proofed” (by upgrading or decommissioning) when sediment delivery to streams is minimized through proactive erosion prevention and erosion control treatments (Figure 1) (Weaver and Hagans, 1999).

Inventoried sites of road-related erosion in the project area fell into one of two treatment categories: 1) upgrade sites - defined as sites on maintained roads that are to be retained for administrative use, land management and fire access, and 2) decommission sites - defined as sites exhibiting the potential for future sediment delivery that have been recommended for either temporary or permanent closure. The upgrading and decommissioning recommendations are primarily aimed at high risk roads and road segments located within streamside, mid-slope, and ridge top areas. In our preliminary analysis of the 503 miles of USFS mapped roads located in the Biscuit Fire area, we identified 74 miles of streamside roads, 135 miles of mid-slope roads and 294 miles of ridge roads (PWA, 2004). Generally, roads on mid-slope areas and on steep lower hillslopes have more stream crossings and larger, more frequent erosion problems, and they deliver more sediment to streams.

The majority of roads and sites in our 135 mile stratified sample of inventoried roads have been proposed for upgrading. This includes upgrading a number of existing roads that are located in stable locations that still exhibit the potential for future sediment delivery. Upgrading typically consists of properly installing new culverts designed to accommodate the 100-year return interval peak storm flow, including debris in transport. A “storm-proofed” road includes a critical dip on a rocked or native road surface or an emergency overflow pipe on a paved road surface to prevent stream diversion (Figure 1). Upgrading also includes improving the road surface and ditch

Figure 1. Characteristics of storm-proofed roads (modified from CDFG, 2004 and Weaver and Hagans, 1999)

The following abbreviated criteria identify common characteristics of “storm-proofed” roads. Roads are “storm-proofed” when sediment delivery to streams is strictly minimized. This is accomplished by dispersing road surface drainage, preventing road erosion from entering streams, protecting stream crossings from failure or diversion, and preventing failure of unstable fills which would otherwise deliver sediment to a stream. Minor exceptions to these “guidelines” can occur at specific sites within a forest road system.

STREAM CROSSINGS

- ✓ all stream crossings have a drainage structure designed for the 100-year flow, including debris and sediment
- ✓ stream crossings have no diversion potential (functional critical dips are in place)
- ✓ stream crossing inlets have low plug potential (trash barriers & graded drainage)
- ✓ stream crossing outlets are protected from erosion (extended, transported or dissipated)
- ✓ culvert inlet, outlet and bottom are open and in sound condition
- ✓ undersized culverts in deep fills (> backhoe reach) have emergency overflow culvert
- ✓ bridges have stable, non-eroding abutments & do not significantly restrict 100-year flood flow
- ✓ fills are stable (unstable fills are removed or stabilized)
- ✓ road surfaces and ditches are “disconnected” from streams and stream crossing culverts
- ✓ decommissioned roads have all stream crossings completely excavated to original grade
- ✓ Class 1 (fish) streams accommodate fish passage

ROAD AND LANDING FILLS

- ✓ unstable and potentially unstable road and landing fills are excavated (removed)
- ✓ excavated spoil is placed in locations where eroded material will not enter a stream
- ✓ excavated spoil is placed where it will not cause a slope failure or landslide

ROAD SURFACE DRAINAGE

- ✓ road surfaces and ditches are “disconnected” from streams and stream crossing culverts
- ✓ ditches are drained frequently by functional rolling dips or ditch relief culverts
- ✓ outflow from ditch relief culverts does not discharge to streams
- ✓ gullies (including those below ditch relief culverts) are dewatered to the extent possible
- ✓ ditches do not discharge (through culverts or rolling dips) onto active or potential landslides

drainage by utilizing a variety of treatments designed to disperse surface runoff and disconnect road and ditch runoff from the natural stream system. Such treatments include frequent rolling dips, ditch relief culverts, berm removal, and/or road surface shaping (including insloping, outloping and crowning). In a few locations not amenable to typical drainage measures, sediment basins have been recommended to lessen fine sediment delivery from the road surface during wet winter months.

Recommended erosion prevention work also includes decommissioning abandoned roads that exhibit the potential for future sediment delivery. Most abandoned, tank-trapped and/or closed roads have been recommended for decommissioning. Many of these roads still have culverted stream crossings that are not being maintained, as well as connected lengths of insloped road that need to be properly and frequently drained. Decommissioning consists of excavating stream crossing fills, restoring altered channels to their natural channel gradients and contouring stream banks back to the natural hillslope gradient or to a stable 2:1 slope grade (Weaver and Hagans, 1994b; USDA, 1993). Decommissioning roads also includes cutting off and dispersing road surface and ditch drainage by utilizing road surface treatments such as ripping and the installation of frequent cross road drains (CDFG, 2004). Partially excavated stream crossings with road fill still remaining in the crossing have been recommended for proper decommissioning (complete excavation). Simply closing a road with a tank-trap is not an acceptable method for road decommissioning or closure. Roads identified as abandoned, closed, and/or tank-trapped, and not properly decommissioned, should be identified as roads with a high priority to apply storm-proofing techniques (Figure 1).

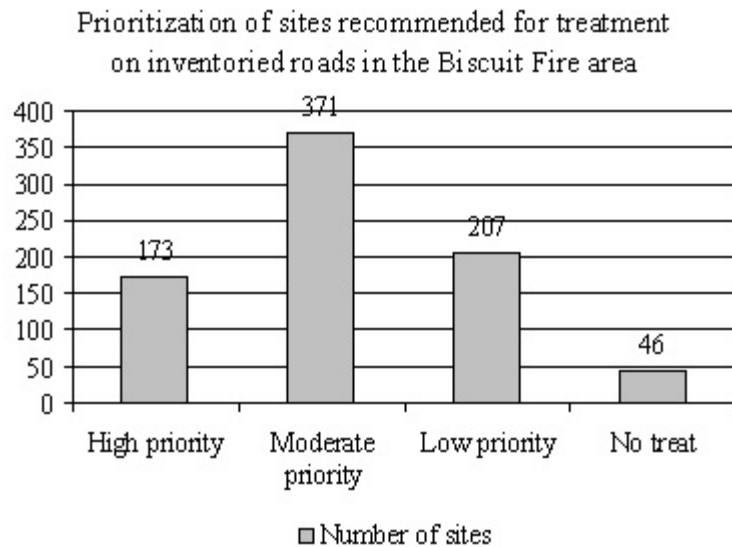
Table 5 lists the types of site-specific treatments that have been recommended for all inventoried sites recommended for erosion control or erosion prevention work in the Biscuit Fire area, including both upgrading and decommissioning. Appendices 2, 3, and 4 outline the types of sites, treatment priorities and recommended treatments, respectively, for all inventoried roads. All standard erosion prevention and erosion control work is designed to properly “storm-proof” roads (through upgrading or decommissioning) and follow the generally accepted criteria outlined in Figure 1.

Based on the 135 miles of inventoried road in this reconnaissance inventory, 753 treatment sites have been prioritized for erosion prevention or erosion control treatments (Table 1 and Table 3). Altogether, 544 sites are identified as having a high or moderate treatment immediacy (173 High or High-Moderate; 371 Moderate or Moderate-Low; see Table 3). Higher priority sites typically show signs of erosion and sediment delivery to the stream channel network, and these are the most likely to erode or fail, thereby delivering sediment. Roughly 22% or 173 sites have a high or moderately high treatment priority (Table 3). They have the highest overall priority for erosion prevention or erosion control treatment.

Appendices 2, 3 and 4 tabulate the full results of the reconnaissance inventory and of the recommendations outlined for each road. All roads proposed for prioritized treatment currently threaten to deliver sediment to the key watersheds if they are left untreated. A number of sites have already failed and others are currently eroding. Older road in mid-slope positions have been

identified elsewhere as potentially important contributors to increased watershed sediment production and delivery (Wemple, et al., 2001), and the same appears to hold true in these watersheds.

Sediment sources along the road systems were found to be relatively frequent, and proper erosion control techniques can be employed to disperse road surface runoff, prevent road surface erosion from being delivered to streams, protect stream crossings from episodic (storm-triggered) failure or stream diversion, and prevent failure of unstable fills that would otherwise deliver sediment to streams (Figure 1).



Over 3,190 recommendations for site-specific erosion control treatments have been prepared for the 751 sites recommended for treatment along 135 miles of inventoried road in the Biscuit Fire road assessment (Table 5; Appendix 4a - 4f). The nature and specifications for typical treatment are more fully defined elsewhere (e.g., CDFG, 2004; Burroughs and King, 1989; Harr and Nichols, 1993; Weaver and Hagans, 1994).

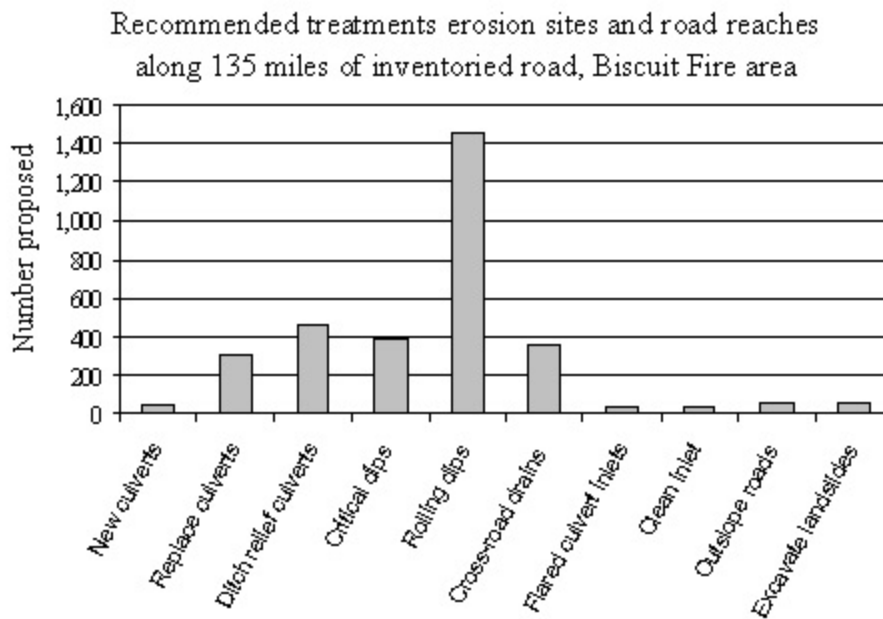


Table 5. Recommended erosion control / erosion prevention treatments to reduce future sediment delivery, by watershed, Biscuit Fire Restoration Project, Southern Oregon.

Proposed Treatments	Inventoried Watersheds						Totals
	Chetco River	Illinois River/ Josephine Creek Watershed	Indigo Creek Watershed	Lawson Creek Watershed	Pistol Creek Watershed	Silver Creek Watershed	
Install CMP	5	3	20	8	3	7	46
Replace CMP	89	64	63	52	19	15	302
Construct Armored Fill	2	6	0	0	0	2	10
Install DRC	218	146	38	0	42	6	450
Construct Critical Dip	129	57	114	54	19	12	385
Construct Rolling Dip	367	99	469	369	31	125	1,460
Construct Cross Road Drain	59	188	99	0	0	8	354
Construct Sediment Basin	0	4	0	0	0	0	4
Clean Ditch	0	0	1	0	0	0	1
Add Flared Inlet	15	9	6	0	0	0	30
Clean CMP Inlet	1	1	24	0	0	4	30
Outslope Road or Road Reach	(22) 15,895'	(21) 8,565'	(1) 500'	0	(13) 10,270'	(3) 1,820'	(60) 37,050'
Excavate and Remove Road Fill ¹	13	10	23	4	0	6	56
Realign Road	0	3	0	0	0	0	3
Number of Proposed Treatments	920	611	858	487	127	188	3,191

¹ Unstable road fill removed from stream crossings and potential landslides. All removed material will be stored in a safe and stable spoil area.

Restoration Costs

Erosion prevention and erosion control for forest road systems varies substantially with location, methodology, standards and local economic conditions. A host of factors can affect the costs of both road upgrading and road decommissioning (CDFG, 2004; Weaver and Hagans, 2004). Prior to field assessment work in the Biscuit Fire area, a preliminary “office” estimate for road “restoration” (sediment control) costs was prepared (Appendix 5). Mapped roads were divided into surface categories and then partitioned into one of three hillslope positions: ridge, midslope, and streamside. Surfaced roads and roads in middle hillslope positions (where stream crossing frequency is high) are likely to be associated with high upgrading and decommissioning costs.

Road treatment costs were developed and assigned to the different road classes and hillslope positions for each of the task in the overall road restoration and erosion prevention project. These tasks include: 1) conduct detailed field assessment and prepare prioritized, site-specific erosion prevention and erosion control plans and prescriptions, and 2) perform road restoration (upgrading and decommissioning).

Observations from our reconnaissance field inventory suggests that our original assessment of unit road upgrading and road decommissioning costs is probably somewhat high, perhaps by 15%. The average stream crossing volume appears slightly smaller than typical and many are already appropriately sized; thereby needing less complex, less costly and less frequent road upgrading treatments. Many culverted stream crossings will not need to be immediately replaced and upgraded.

However, several factors have more than counterbalanced this potential cost savings. First, there are approximately 220 more miles of forest road than we originally used to derive the preliminary restoration cost estimate (Appendix 5). These 220 miles of roads are the ones that we found through our air photo analysis of the planning watersheds, but that do not show up on either the USFS maps or the digital GIS layers provided to us. Secondly, we prepared the original cost estimate using locally competitive heavy equipment rental rates and labor rates. It is likely that federal prevailing wage rates will apply to these “public works” projects. If so, costs for heavy equipment and labor crews could add another 25% to 30% to the preliminary estimate for these activities. As a result, overall restoration costs are expected to rise about 45% from the preliminary estimate (Table 6).

Estimated road treatment costs range from \$27.5 to \$40 million for all roads in the Biscuit Fire area. These figures are in agreement with our independently derived cost estimate based on implementing all the proposed treatments for the 135 miles reconnaissance assessment (see bar graph figure, below), extrapolated over the full 728 miles of forest and mining roads. Both estimates were developed under the assumption that all sites of future sediment delivery along 728 miles of road will be treated, regardless of their relative priority or likelihood of failures. This is unlikely, as many land owners chose to address the most important work sites during their initial restoration efforts. In this manner, less significant or less costly treatment sites can be addressed as a part of normal, annual road maintenance operations. In this and other ways,

transportation planning and treatment prioritization can be used to address high priority sites in critical areas with the monies that are made available for restoration work.

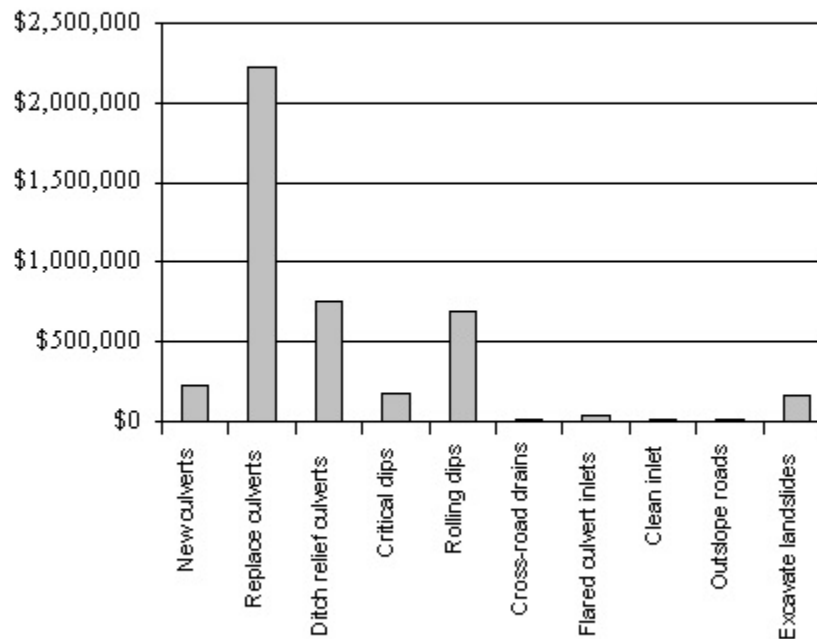
Table 6. Original and revised cost estimate for Biscuit Fire Area Road Restoration Costs.		
Cost Category	Lower Cost Estimate	Upper Cost Estimate
Conduct Prioritized Road Assessment	\$477,000	\$586,000
Perform Road Restoration (primarily road upgrading)	\$13,000,000	\$19,000,000
Road Assessment plus Road Restoration	\$13,477,000	\$19,586,000
USFS Project Management (+/- 25% for NEPA, contracting, coordination with contractors, monitoring, etc.)	\$3,370,000	\$4,900,000
Sub Total	\$16,847,000	\$24,486,000
Contractors, Non-Profit Overhead (12%)	\$2,021,000	\$2,938,000
Total Budget (original cost estimate)	\$18,868,000	\$27,424,000
<i>Cost adjustment for existing conditions (-15 % for equipment only)</i>	<1,950,000>	<2,850,000>
<i>Cost added for 220 added road miles (assessment + restoration + administrative overhead costs)</i>	7,368,000	10,710,000
<i>Cost added for prevailing wage rates (est 25% for restoration work only)</i>	3,250,000	4,750,000
Total Revised Cost Estimate	\$27,536,000	\$40,034,000

Conclusions

This project is the result of the streamlined reconnaissance assessment of a 135 miles sample of roads in the Biscuit Fire area. Roads were selected to include a variety of geologic materials, physiographic settings, climate conditions and slope positions. A broader objective would be to complete a comprehensive, prioritized erosion control plan for the eleven key watersheds by conducting a quantitative forward-looking erosion inventory all the roads depicted on the basin map (or as identified on the ground) and developing site-specific, prioritized treatment prescriptions for all sites of existing or future erosion and sediment delivery. The expected benefit of completing the erosion control and prevention planning work lies in the reduction of long term road-related sediment delivery to the key watersheds in the Biscuit Fire area.

A critical first-step in the overall risk-reduction process is the development of a comprehensive watershed plan for all the watersheds affected by the fire. The complete inventory would address

Selected road upgrade costs for inventoried sites and road reaches along 135 miles of forest road in the Biscuit Fire area



the identification, analysis and treatment of sites of episodic erosion and sediment delivery as well as treatment of hydrologically-connected road reaches currently contributing to chronic fine sediment delivery (Map 1). This assessment would include both maintained and abandoned roads, and would include roads that are on the USFS road system and those that are not depicted on USFS maps. The final goal of this effort would be to efficiently and cost-effectively eliminate or reduce the existing and potential road-related sediment sources in the eleven key watersheds.

This is a proactive restoration strategy that employs quantitative methods to identify sites, assign risk, develop cost-effective treatments and assign overall priorities based on both risk and beneficial uses of the affected streams and rivers. The process employs techniques to “storm-proof” each watershed’s road system (including road upgrading and road decommissioning), as well treatments designed to “disconnect” roads from natural streams in the assessment area. In developing this plan, all roads in the Biscuit Fire area should be considered for either upgrading or decommissioning, depending upon the risk of erosion and sediment delivery to streams, as well as future management needs.

Good land stewardship requires that roads either be upgraded and maintained, or intentionally closed (“put-to-bed”). The old practice of abandoning roads, by either installing barriers to traffic (logs, “tank traps” or gates) or simply letting them naturally revegetate, is no longer considered acceptable. These roads typically continue to fail and erode for decades following abandonment, as was the observed effects along several such abandoned roads that we

inventoried in the Biscuit Fire assessment area. The proper word for proactive road closure is decommissioning (USDA, 1993; CDFG, 2004). Decommissioning may be either permanent or temporary, but the treatments are largely the same. Properly decommissioned roads no longer require maintenance and are no longer sources of accelerated erosion and sediment delivery to a watershed's streams. The impacts of reopening old, abandoned roads so that they can be correctly decommissioned has been evaluated on a case-by-case basis, but the benefits (large reductions in long term erosion) almost always far outweigh the negative effects (small, short-term increases in erosion from bare soil areas).

Road upgrading consists of a variety of techniques employed to "storm-proof" a road and prevent unnecessary future erosion and sedimentation (Weaver and Hagans, 1999; CDFG, 2004). Storm-proofing typically consists of stabilizing slopes and upgrading drainage structures so that the road is capable of withstanding both annual winter rainfall and runoff, as well as a large magnitude storm events without failing or delivering excessive sediment to the stream system. The goal of road upgrading is to strictly minimize the contributions of fine sediment from roads and ditches to stream channels, as well as to minimize the risk of serious erosion and sediment yield when large magnitude, infrequent storms and floods occur. The tasks employed for both road upgrading and road decommissioning treatments (Table 5; Figure 1) typically involve the application of heavy earth-moving equipment and skilled equipment operators and forest workers in a process that is both beneficial for watershed protection as well as for the local economy.

References cited

Beschta, R.L, J.J. Rhodes, J.B. Kauffman, R.E. Gresswell, G.W. Minshall, J.R.Karr, D.A. Perry, F.R. Hauer, and C.A. Frissell. 2004. Post-fire management on forested public lands of the Western United States. *Conservation Biology*, 18(4). 957-967.

Beschta, Robert L. et al, 1995, *Wildfire and Salvage Logging: Recommendations for Ecologically Sound Post-Fire Salvage Logging and Other Post-Fire Treatments on Federal Lands in the West*, distributed by Pacific Rivers Council, 1995, 14 pages.

Burroughs, E.R. and J.G. King. 1989. *Reduction of soil erosion on forest roads*. USDA Forest Service, Intermountain Research Station. General Technical Report INT-264. 19 pages.

California Department of Fish and Game (CDFG). 2004. Upslope Assessment and Restoration Practices, Chapter 10, California Salmonid Restoration Manual, 3rd Edition. Inland Fisheries Division. 91 pages plus appendices.

Furniss, M., S. Flanagan and B. McFadin. 2000. *Hydrologically-connected roads: An indicator of the influence of roads on chronic sedimentation, surface water hydrology and exposure to toxic chemicals*. IN: Stream Notes. Stream Systems Technology Center. Rocky Mountain Research Station. USDA Forest Service. July, 2000. 5-7.

Furniss, M. J.; Roelofs, T. D.; Yee, C. S. 1991. *Road construction and maintenance*. In: Meehan, W. R., ed. Influences of forest and rangeland management on salmonid fishes and their habitats. Chapter 8. American Fisheries Society Special Publication 19:297-323.

Harr, R.D. and R.A. Nichols, 1993, Stabilizing forest roads to help restore fish habitats: A Northwest Washington example. Fisheries. Vol.18, no. 4. pages 18-22.

Luce, C.H., B.E. Rieman, J.B. Dunham, J.L. Clayton, J.G. King, and T.A. Black. 2001. *Incorporating aquatic ecology into decisions on prioritization of road decommissioning*, Water Resources IMACT, 3(3), pages 8-14.

Pacific Watershed Associates, 2004, Phase 1 Restoration Cost Estimate for Road-Related Erosion Control and Prevention in the Biscuit Fire Area, Southern Oregon. Unpublished Technical Report. Arcata, CA. 5 pages.

Pacific Watershed Associates. 1994a. Dumont Creek watershed assessment report: an erosion inventory and plan of action for erosion prevention and erosion control, Dumont Creek, Umpqua National Forest, Oregon. Prepared for the U.S. Forest Service, Umpqua National Forest, Roseburg, Oregon, and the Pacific Rivers Council, Eugene, Oregon, 85 pages + appendices.

Pacific Watershed Associates. 1994b. Handbook for forest and ranch roads. Prepared for the Mendocino County Resource Conservation District in cooperation with the California Dept. of Forestry and the U.S. Soil Conservation Service. Mendocino Resource Conservation District, Ukiah, California. 163 pages.

Reid, L.M. and T. Dunne. 1984. *Sediment production from forest road surfaces*. Water Resources Research 20:1753-1761.

U.S. Department of Agriculture (U.S. Forest Service), 1993, "Forest Ecosystem Management: An Ecological, Economic and Social Assessment." Forest Ecosystem Management Assessment Team (FEMAT), Interagency SEIS Team, Portland, Oregon.

Weaver, W.E. and R.A. Sonnevil. 1984. Relative cost-effectiveness of erosion control for forest land rehabilitation, Redwood National Park. In: *Erosion Control...Man and Nature*, Proceedings of Conference XV, Int'l Erosion Control Assoc, Feb 23-24, 1984, Denver, CO. pages 83-115.

Weaver, W.E., M.M. Hektner, D.K. Hagans, L.J. Reed, R.A. Sonnevil, G.J. Bundros. 1987a, An Evaluation of Experimental Rehabilitation Work, Redwood National Park. Redwood National Park Technical Report 19. National Park Service, Redwood National Park. Arcata, California. 163 p.

Weaver, W.E., D.K. Hagans and M.A. Madej. 1987b. Managing forest roads to control cumulative erosion and sedimentation effects. In: Proceedings of the California watershed management conference, Report 11 (18-20 Nov. 1986, West Sacramento, Calif.), Wildland Resources Center, Univ. of California, Berkeley, California. 6 pages.

Weaver, W.E. and D.K. Hagans, 2004, Road upgrading, decommissioning and maintenance: Estimating costs on small and large scales. In: Proceedings, National Marine Fisheries Service Salmonid Habitat Restoration Cost Workshop. Portland, Oregon, November 14-16, 2000.

Weaver, William E., Danny K. Hagans, and James H. Popenoe. 1995. Magnitude and causes of gully erosion in the lower Redwood Creek basin, Northwestern California. U.S. Geological Survey Professional Paper 1454I. Pages I1-I21.

Weaver, W.E. and D.K. Hagans. 1999. Storm-proofing forest roads. In: Proceedings of the Skyline Forest Sedimentation Conference, Corvallis, Oregon. April, 1999, pages 230-245.

Weaver, W.E. and D.K. Hagans. 1996. Sediment treatments and road restoration: protecting and restoring watersheds from sediment-related impacts. Chapter 4, IN: Healing the Watershed, A Guide to Native Fish Restoration, Pacific Rivers Council, Eugene, Oregon. Pages 109-143.

Weaver, W.E. and R.A. Sonnevil. 1984. Relative cost-effectiveness of erosion control for forest land rehabilitation, Redwood National Park. In: Erosion Control...Man and Nature, Proceedings of Conference XV, Int'l Erosion Control Assoc, Feb 23-24, 1984, Denver, CO. pages 83-115.

Wemple, B. C. and J. A. Jones. 2003. Runoff production on forest roads in a steep, mountain catchment" Water Resources Research, 39(8), doi 10.1029/2002WR001744.

Wemple, B. C., F. J. Swanson, and J. A. Jones, 2001. Forest roads and geomorphic process interactions, Cascade Range, Oregon. Earth Surface Processes and Landforms, 26: 191-204.

Wemple, B. C., J. A. Jones and G. E. Grant, 1996. Channel network extension by logging roads in two basins, Western Cascades, Oregon." Water Resources Bulletin, 32(6): 1195-1207.

Wemple, B.C.. 1994. Hydrologic integration of forest roads with stream networks in two basins, western Cascades, Oregon. Oregon State University. M.S. Thesis.

APPENDICES

Appendix 1 - *Summary Assessment Results for Six Planning Watersheds*

Appendices 2a - 2f

Sites of future road-related erosion and sediment delivery - Separated by watershed, these tables outline the number of inventoried sites with potential for sediment delivery to streams, the number of sites recommended for treatment and the connected road and/or ditch length to the stream system, by road.

Appendices 3a - 3f

Site specific treatment priorities for all inventoried sediment sources in the Biscuit Fire area. - This table outlines the treatment priority for sites identified in each inventoried watershed, by road. The table includes information regarding the volume of potential future sediment delivery by size class.

Appendices 4a - 4f

Recommended treatments along all inventoried roads in the Biscuit Fire area. - Separated by watershed, these tables list the site specific treatments for all inventoried sites recommended for erosion prevention work in the Biscuit Fire area. Recommended erosion prevention work includes roads that have future sediment delivery plus recommended road surface drainage improvements.

Appendix 5 - *Preliminary Restoration Cost Estimate for Road-Related Erosion Control and Erosion Prevention in the Biscuit Fire Area, Southern Oregon*

APPENDIX 1

Summary Assessment Results
for Six Planning Watersheds

Appendix 1 - Summary Assessment Results for Six Planning Watersheds

Not all the planning watersheds within the Biscuit Fire area were sampled or inventoried for this reconnaissance restoration planning assessment. Similarly, only a limited stratified sample of roads were assessed within each of the six inventoried watersheds (Table 1).

Chetco River Planning Watershed

East of Brookings, Oregon in the Chetco Creek planning watershed in the western portion of the Biscuit Fire area we inventoried 23.4 miles of road on 9 different USFS roads (Table 1; Appendix 1a, 2a and 3a; Map 1). In addition to the roads identified on the USFS road maps and GIS, nearly 27 miles of additional roads were identified during our aerial imagery analysis (Table 2). Field crews inventoried 174 sites, including 147 stream crossings, 8 potential landslides and 19 road surface drainage problems. Although 7.4 sites per mile is a high site density, we did note some good qualities about the road's general design. Long lengths of streamside road are paved on the Wild and Scenic portions of the Chetco. Stream crossing culverts are adequately sized for the drainage areas. Ditch relief culverts are placed where required for road maintenance and are not delivering to the stream network. Road surfaces are paved and rocked and road surface shapes are generally outsloped and along ridge top or mid-slope hillslope positions, and not in the inner gorge.

We inventoried approximately 7.4 sediment delivery sites per mile and have recommended site treatments and road drainage improvements as a part of road upgrading. Most of the 18" culverts at inventoried stream crossings are undersized for the 100-year flood flows and are undersized to pass the debris at flood levels. The majority of the stream crossings have a diversion potential and a high to moderately high culvert plug potential. A few culverts are installed high in the fill and not installed at the base of the fill. A few culverts are plugged by post-fire runoff, small to medium woody debris and dense revegetation around the culvert inlets. Unstable road fills have not been treated (stabilized) or removed. Fine road surface runoff and sediment drains to most stream crossings. Ditch lengths are very long on insloped roads. Lengths range from 500' to 2,500' without a drainage structure. From the total 23.4 mile inventory, over 83% of the road length is currently connected and delivers runoff and fine sediment to the stream system (Table 1).

Illinois River/ Josephine Creek Planning Watershed

West of Cave Junction and Selma, Oregon in the Illinois River/ Josephine Creek planning watershed, in the eastern portion of the Biscuit Fire area, we inventoried nearly 16.0 miles of road on four different USFS roads (Table 1; Appendix 1b, 2b and 3b; Map 1). In the planning watershed, we identified nearly 83% of the 16 miles of inventoried road hydrologically connected and draining to the stream channel network. Fifty six (56) stream crossings have a diversion potential and 16 are currently diverted out of their natural channel (Appendix 1b). Prioritized treatment sites include 99 stream crossings, one (1) potential landslide and 62 road surface drainage locations where treatments call for disconnecting road surface drainage.

Roads in Josephine Creek watershed are not impacted by post-fire erosion as much as the other roads in other key watersheds. However, in this watershed assessment area the shallow, rocky

soils have little capacity for water storage, leading to high runoff to rainfall ratios. Sites of potential future road-related sediment delivery are frequent in this geology type and over 150 sites are recommended for treatment to prevent or control erosion. Field crews inventoried 162 sites at a rate of 10.1 sediment delivery sites per mile of inventoried road. Insloped roads, old mining flumes, through-cuts and inboard ditches capture and concentrate surface runoff, often causing rills or gullies that deliver runoff and sediment to the streams. Road surface runoff and fine sediment drains to most stream crossings. The majority of road approaches to wet fords are not disconnected and show evidence of fine sediment delivering to the stream crossing. A long section of Road 092B and several other roads are not properly decommissioned and they are currently “closed” behind tank-traps or washed-out stream crossings.

In another sub-basin, portions of USFS Road 4103, the Illinois River Road, are paved. Approximately 70% of the inventoried sites are on this road. Some of the engineered portions of the road have large fill volumes and high headwalls. Several culverts have a low chance of failure because of the high headwalls engineered into their design. More effort can be made to disconnect the road and ditch runoff from delivering fine sediment to these and other stream crossings. Fine road surface and turnout runoff, cutbank ravel and ditch sediment drains to most stream crossings and ditch lengths are very long. Ditches range from 100' to 2,500' without a ditch relief culvert. Disconnecting this road runoff from the Wild and Scenic Illinois River is a high priority.

We inventoried three stream crossings with plugged culverts. In addition, approximately 16% of the inventoried culverted stream crossings have a high or high-moderate plug potential. We inventoried one unstable road fill that needs to be excavated before it fails and delivers sediment. Finally, in many locations ditch relief culverts are not installed frequently enough to effectively drain the road and ditch without delivering fine sediment to the stream network (Figure 1). Long ditch lengths cause hillslope gullies along the inner gorge of the Illinois River’s main stem and result in additional points of connectivity between the road system and the nearby stream channels (Wemple et al., 1996). More frequent placement of ditch relief culverts are recommended to break up long sections of eroding, connected ditch lengths and contributing road reaches.

Indigo Creek Planning Watershed

In the Indigo Creek planning watershed in the northwest portion of the Biscuit Fire area we inventoried nearly 47.0 miles of road on 26 different USFS roads (Table 1; Appendix 1c, 2c and 3c; Map 1). Field crews inventories identified 241 sites of potential or existing sediment delivery, including 172 stream crossings, 16 potential landslides and 53 road surface drainage problems (Map 2). Fifty (50) treatment sites have a high or moderately high treatment immediacy (Map 3). Over 690 proposed recommendations for site-specific erosion prevention and control treatments have been prepared for 47.0 miles of inventoried road (Appendix 3c).

Storm-proofing standards are met where stream crossing culverts are adequately sized for the drainage areas and 100-year peak flows. Ditch relief culverts are frequently placed where they are required for road maintenance and are not delivering sediment to the stream network. Road

surfaces are rocked and shapes are generally outsloped and along ridge top or mid-slope hillslope positions, and not in the inner gorge (Map 2).

Treatment sites in this watershed average 5.1 existing or potential sediment delivery sites per mile. Most inventory sites do not meet generally accepted “storm-proof” design standards (Figure 1) and have been recommended for upgrading or decommissioning. Based on field evidence, most of the 18" culverts at stream crossings appear undersized for the 100-year flood flows and are undersized to pass the debris that will be transported down the channels. The majority of the

stream crossings have a diversion potential and a high to moderately high culvert plugging potential, although only a few culverts are not installed properly at the base of the stream crossing's fill. Several stream crossing culverts are currently plugged because of post-fire runoff, small to medium woody debris and dense revegetation around the culvert inlets. The inventory identified 16 unstable road fills that may fail and deliver to the stream network if left untreated. Six of the potential landslides are judged as having a high or moderately high treatment priority. Road surface runoff and fine sediment drains to most stream crossings and ditch lengths are very long on insloped roads. The inventory revealed that 42% of the 47.0 miles of inventoried road length is currently connected to the stream channel system, thereby delivering road surface runoff and fine sediment from eroding cutbanks and bare soil areas to nearby stream channels. Some USFS roads have been “tank trapped” (blocked) and need to be properly decommissioned to eliminate or reduce the potential for potential road-related erosion and sediment delivery.

Lawson Creek Planning Watershed

In the Lawson Creek planning watershed in the northwest portion of the Biscuit Fire area we inventoried 21.0 miles of road on 16 different USFS roads (Table 1; Appendix 1d, 2d and 3d; Map 1). Field crews inventoried 126 sites of existing or potential sediment delivery, including 89 stream crossings, 12 potential landslides and 25 road surface drainage problems. USFS Road 301 was not impacted by post-fire erosion as much as the other roads in the watershed. Several roads are not properly decommissioned but have been “closed” behind “tank-traps” or washed-out stream crossings. Treatment sites average 6.0 existing or potential sediment delivery sites per mile. Site specific treatments are necessary at 126 sites and over 683 proposed recommendations for have been prepared for the 21.0 miles of inventoried road. Most of the stream crossings have a diversion potential and 18 are currently diverted out of there natural channel (Appendix 1d). Approximately 29% of the inventoried culverted stream crossings exhibit a high or high-moderate plug potential, and 13 stream crossings currently have plugged culverts. Potentially unstable road fills are proposed for removal at 12 sites. Finally, road-stream connectivity is significant in this assessment area with surface runoff and fine sediment delivering to most stream crossings. Ditch lengths are typically very long, ranging from 100' to 2,500' without a ditch relief culvert or other drainage structure to disperse concentrated road runoff. A number of the existing rolling dips are not functional (there is insufficient reverse grade) and over nine miles of inventoried road and ditch (43% of the inventoried length) is currently connected to the stream network.

Pistol River Planning Watershed

In the Pistol River planning watershed in the western portion of the Biscuit Fire area we inventoried 2.9 miles of USFS road (Table 1; Appendix 1e, 2e and 3e; Map 1). Field crews inventoried 27 sites including 23 stream crossings and 4 road surface drainage problems. Over 127 recommendations have been proposed for site specific treatments for approximately 3.0 miles of road. Based on field observations and calculations, stream crossing culverts do not appear to be adequately sized for their drainage areas and 19 of 23 culverts are undersized for the 100-year flood flows. The majority of the stream crossings have a diversion potential and a high to moderately high culvert plugging potential. A few culverts are not installed properly, high in the fill at the culvert outlet and not at the base of the fill at the natural channel bottom. A few (3) culverts have been plugged by post-fire runoff, small to medium woody debris and dense vegetation around the culvert inlets. Although road surfaces are rocked, generally outsloped, and located along ridge top or mid-slope hillslope positions, ditch relief culverts are not placed frequently enough to disperse road surface and ditch runoff and the inventoried roads are nearly 100% connected and delivering to the stream system (Table 1).

Silver Creek Planning Watershed

In the Silver Creek planning watershed, also in the northwest portion of the Biscuit Fire area, we inventoried 22.7 miles of road on eight different USFS Roads (Table 1; Appendix 1f, 2f and 3f; Map 1). Field crews inventoried 67 sites, including 42 stream crossings, six potential landslides, and 19 road drainage problems. The Silver Creek watershed has a comparatively low site density (2.95 sites per mile) and we did identify some good qualities about the general design of the roads that were inventoried. Culverts at stream crossings are adequately sized for the channel dimensions and 100-year flood levels. Rocked rolling dips have been constructed on streamside and mid-slope roads, effectively breaking up continuous lengths of road surface runoff at 80% of the stream crossings. A few of the recent stream crossing upgrades have effective critical dips. Roads are generally outsloped and along ridge top and mid-slope hillslope positions, and not in the inner gorge. The drainage structures on ridge roads are installed such that they generally do not deliver sediment to the stream system.

Thirty two (32) of the inventoried sites of existing or potential sediment delivery are judged as having a high or moderately high treatment priority (Table 3). In general, the most consistent design problems are where a number of 18" culverts have been installed at stream crossings. Most 18 inch culverts are undersized for the 100-year flood flows and are undersized to pass the debris that will be transported in the large events. Eleven (11) stream crossings have a diversion potential and two streams are currently diverted out of their natural channel. Unstable road fills identified at 19 locations have been recommended for removal. Of nearly 23.0 miles of inventoried road in the watershed approximately 24% is connected to the stream system. Ditch lengths are very long and range from 100' to 2,500' without a drainage structure. Concentrated road surface runoff has caused numerous small gullies that deliver sediment to the stream system.

Appendices 2a - 2f

Sites of future road-related erosion and sediment delivery

Separated by watershed, these tables outline the number of inventoried sites with potential for sediment delivery to streams, the number of sites recommended for treatment and the connected road and/or ditch length to the stream system, by road.

Appendix 2a. Reconnaissance road erosion inventory data for USFS roads in the Chetco River watershed, Biscuit Fire area (PRC/PWA, 2004)						
Road name (see map)	Inventoried sites (#)	Sites recommended for treatment (#)	Connected road and/or ditch length (ft) ¹	Diversion potential (#)	Currently diverted (#)	Stream crossing culverts with high or high-moderate plugging potential
Chetco River Watershed						
1376	124	114	71,304	100	7	22
1376 Spur 100	1	1	420	0	0	0
1909	22	22	13,415	17	2	5
1909 Spur 1	3	3	1,100	0	0	0
1909-050	11	11	4,075	7	0	4
1909-200	7	7	8,150	3	0	1
1909-200 Spur 1	1	1	120	0	0	0
1909-200 Spur 2	2	2	3,150	2	1	1
1909-200 Spur 2-B	3	3	1,450	1	1	0
Totals	174	164	103,184	130	11	33
¹ Total road length inventoried = 123,552 feet (23.4 miles); 83.5% of inventoried road are “hydrologically connected” to the stream channel network.						

Appendix 2b. Reconnaissance road erosion inventory data for USFS roads in the Illinois - Josephine Creek watersheds, Biscuit Fire area (PRC/PWA, 2004)

Road name (see map)	Inventoried sites (#)	Sites recommended for treatment (#)	Connected road and/or ditch length (ft) ¹	Diversion potential (#)	Currently diverted (#)	Stream crossing culverts with high or high-moderate plugging potential
Illinois River/Josephine Creek Watersheds						
092	19	19	3,744	8	6	0
092A	1	1	250	0	0	0
092B	10	9	2,050	2	2	0
4103	132	121	64,398	46	8	16
Totals	162	150	70,442	56	16	16
¹ Total road length inventoried = 84,480 feet (16.0 miles); 83% of inventoried road are “hydrologically connected” to the stream channel network.						

Appendix 2c. Reconnaissance road erosion inventory data for USFS roads in the Indigo Creek watershed in the Biscuit Fire area (PRC/PWA, 2004)						
Road name (see map)	Inventoried sites (#)	Sites recommended for treatment (#)	Connected road and/or ditch length (ft) ¹	Diversion potential (#)	Currently diverted (#)	Stream crossing culverts with high or high-moderate plugging potential
Indigo Creek Watershed						
052	24	24	15,980	3	0	3
055	30	30	22,085	18	2	6
071A	3	3	745	1	0	0
150	16	16	6,105	10	1	9
151	17	16	5,545	7	0	7
154	20	20	7,665	9	0	7
154A	4	4	2,330	2	1	2
1577-130	2	2	1,321	1	0	1
1577-130 Spur 1	4	4	740	0	0	1
2308-180	4	4	1,263	1	0	0
3577	11	11	6,234	6	0	1
3577 Spur 1A	5	5	1,636	0	0	0
3577-130	6	6	949	2	0	1
3577-130 Spur 1	10	10	3,397	7	0	6
3577-130 Spur 2	5	5	1,273	2	0	2
440	16	16	6,285	10	6	3
451	5	5	2,400	3	0	1
480	1	1	370	1	0	0
510 Maintained	3	3	250	0	0	0
510 Abandoned	13	12	5,665	1	1	0
511	5	5	3,900	3	0	1
761	16	16	4,025	12	0	1

Appendix 2c (cont). Reconnaissance road erosion inventory data for USFS roads in the Indigo Creek watershed in the Biscuit Fire area (PRC/PWA, 2004)

Road name (see map)	Inventoried sites (#)	Sites recommended for treatment (#)	Connected road and/or ditch length (ft) ¹	Diversion potential (#)	Currently diverted (#)	Stream crossing culverts with high or high-moderate plugging potential
Indigo Creek Watershed						
761A	1	1	200	1	0	0
761B	1	1	150	1	0	0
761C	4	4	1,105	1	0	0
761D	15	14	3,220	10	0	4
Totals	241	238	104,838	112	11	56
¹ Total road length inventoried = 248,160 feet (47.0 miles); 42% of inventoried road are “hydrologically connected” to the stream channel network.						

Appendix 2d. Reconnaissance road erosion inventory data for USFS roads in the Lawson Creek watershed, Biscuit Fire area (PRC/PWA, 2004)						
Road name (see map)	Inventoried sites (#)	Sites recommended for treatment (#)	Connected road and/or ditch length (ft) ¹	Diversion potential (#)	Currently diverted (#)	Stream crossing culverts with high or high-moderate plugging potential
Lawson Creek Watershed						
310	55	55	31,140	34	11	10
3318 Spur 1	4	4	980	0	0	0
3318-310 Spur J-1	9	9	3,760	1	0	0
3318-310 Spur J-1A	1	1	350	0	0	0
3318-310 Spur J-1B	2	1	620	0	0	0
3318-310 Spur J-1C	1	0	845	0	0	0
3318-310 Spur J-1D	1	1	675	0	0	0
3318-310 Spur J-1E	2	2	260	0	0	0
3318-310 Spur J-1F	4	4	2,100	3	3	0
3318-310 Spur J-2	1	1	300	0	0	0
3318-310 Spur J3	10	0	1,320	0	0	0
3680	16	16	11,510	9	2	8
3680 Spur C	10	10	3,227	6	0	6
3680 Spur C-1	3	3	422	1	0	0
3680 Spur C-2	6	6	3,225	2	1	2
3680 Spur C-3	1	1	264	1	1	0
Totals	126	114	60,998	57	118	26
¹ Total road length inventoried = 110,880 feet (21.0 miles); 55% of inventoried road are “hydrologically connected” to the stream channel network.						

Appendix 2e. Reconnaissance road erosion inventory data for USFS roads in the Pistol River watershed, Biscuit Fire area (PRC/PWA, 2004)						
Road name (see map)	Inventoried sites (#)	Sites recommended for treatment (#)	Connected road and/or ditch length (ft) ¹	Diversion potential (#)	Currently diverted (#)	Stream crossing culverts with high or high-moderate plugging potential
Pistol Creek Watershed						
3680-360	17	17	13,650	14	1	4
3680-360-JF	10	10	1,500	5	3	0
Totals	27	27	15,150	19	4	4
¹ Total road length inventoried = 15,150 feet (2.9 miles); 100% of inventoried road are “hydrologically connected” to the stream channel network.						

Appendix 2f. Reconnaissance road erosion inventory data for USFS roads in the Silver Creek watershed, Biscuit Fire area (PRC/PWA, 2004)						
Road name (see map)	Inventoried sites (#)	Sites recommended for treatment (#)	Connected road and/or ditch length (ft) ¹	Diversion potential (#)	Currently diverted (#)	Stream crossing culverts with high or high-moderate plugging potential
Silver Creek Watershed						
050	14	13	4,320	3	0	3
065	1	1	350	1	0	0
090	22	21	9,050	3	1	3
090A	1	1	400	0	0	0
090B	1	0	80	0	0	0
091	17	14	7,749	0	0	2
361	6	6	2,210	3	0	3
665	5	4	4,200	1	1	0
Totals	67	60	28,359	11	2	11
¹ Total road length inventoried = 119,856 feet (22.7 miles); 23.6% of inventoried road are “hydrologically connected” to the stream channel network.						

Appendices 3a - 3f

Site specific treatment priorities for all inventoried sediment sources in the Biscuit Fire area.

This table outlines the treatment priority for sites identified in each inventoried watershed, by road. The table includes information regarding the volume of potential future sediment delivery by size class.

Appendix 3a. Treatment priority (Treatment Immediacy) and potential episodic sediment source volumes for inventoried USFS roads in the Chetco River Watershed, Biscuit Fire Area (PRC/PWA, 2004)

Road Name (see map)	Treatment Immediacy (H, HM, M, ML, L) ¹				Estimated volume of sites (potential sediment delivery volume) ²					Type of sites
	H;HM	M;ML	L	NO	S	M	L	XL	XXL	
1376	28	40	46	10	59	36	17	8	4	111 stream crossings, 6 gullies, 5 landslides, 1 ditch relief culvert, 1 spring
1376 Spur 100	0	0	1	0	1	0	0	0	0	1 gully
1909	4	15	3	0	9	7	5	0	1	20 stream crossings, 1 ditch relief culvert, 1 gully
1909 Spur 1	3	0	0	0	3	0	0	0	0	2 gullies, 1 landslide
1909-050	5	6	0	0	1	4	2	2	2	9 stream crossings, 1 landslide, 1 gully
1909-200	2	4	1	0	4	3	0	0	0	3 stream crossings, 2 gullies, 1 landslide, 1 ditch relief culvert
1909-200 Spur 1	0	1	0	0	1	0	0	0	0	1 gully
1909-200 Spur 2	2	0	0	0	1	1	0	0	0	2 stream crossings
1909-200 Spur 2-B	0	3	0	0	3	0	0	0	0	2 stream crossings, 1 gully
3318 Spur 1	2	2	0	0	1	3	0	0	0	4 stream crossings
3318-310 Spur J3	0	0	0	10	10	0	0	0	0	10 stream crossings
Totals	46	71	51	20	93	54	24	10	7	

¹ Treatment priority: H = High; HM = High-Moderate; M = Moderate; ML = Moderate-Low; L = Low, NO = No treat.

² Volume size classes (cubic yards): Small (S) = 0-100; Medium (M) = 100-500; Large (L) = 500-1,000; XL = 1,000-5,000; XXL = >5,000.

Appendix 3b. Treatment priority (Treatment Immediacy) and potential episodic sediment source volumes for inventoried USFS roads in the Illinois River and Josephine Creek Watershed, Biscuit Fire Area (PRC/PWA, 2004)

Road Name (see map)	Treatment Immediacy (H, HM, M, ML, L) ¹				Estimated volume of sites (potential sediment delivery volume) ²					Type of sites
	H;HM	M;ML	L	NO	S	M	L	XL	XXL	
092	0	10	9	0	19	0	0	0	0	15 stream crossings, 3 gullies, 1 spring
092A	0	0	1	0	1	0	0	0	0	1 stream crossing
092B	0	8	1	1	8	2	0	0	0	7 stream crossings, 2 gullies, 1 spring
3318-310 Spur J-1	6	3	0	0	4	4	0	1	0	5 gullies, 2 landslides, 2 stream crossings
3318-310 Spur J-1A	0	1	0	0	1	0	0	0	0	1 stream crossing
3318-310 Spur J-1B	0	0	1	1	2	0	0	0	0	2 gullies
3318-310 Spur J-1C	0	0	0	1	1	0	0	0	0	1 stream crossing
3318-310 Spur J-1D	0	1	0	0	1	0	0	0	0	1 gully
3318-310 Spur J-1E	0	1	1	0	1	1	0	0	0	1 stream crossing, 1 gully
3318-310 Spur J-1F	3	1	0	0	2	2	0	0	0	4 gullies
3318-310 Spur J-2	1	0	0	0	0	1	0	0	0	1 gully
4103	4	76	41	11	84	30	8	7	3	76 stream crossings, 43 ditch relief culverts, 8 springs, 4 gullies, 1 landslide
Totals	14	101	54	14	124	40	8	8	3	

¹ Treatment priority: H = High; HM = High-Moderate; M = Moderate; ML = Moderate-Low; L = Low; NO = No treat.

² Volume size classes (cubic yards): Small (S) = 0-100; Medium (M) = 100-500; Large (L) = 500-1,000; XL = 1,000-5,000; XXL = >5,000.

Appendix 3c. Treatment priority (Treatment Immediacy) and potential episodic sediment source volumes for inventoried USFS roads in the Indigo Creek Watershed, Biscuit Fire Area (PRC/PWA, 2004)

Road Name (see map)	Treatment Immediacy (H, HM, M, ML, L) ¹				Estimated volume of sites (potential sediment delivery volume) ²					Type of sites
	H;HM	M;ML	L	NO	S	M	L	XL	XXL	
052	6	17	1	0	13	7	3	1	0	12 stream crossings, 9 ditch relief culverts, 2 landslides, 1 spring
055	3	15	12	0	6	17	7	0	0	26 stream crossings, 2 ditch relief culverts, 1 landslide, 1 road bed
071A	0	3	0	0	2	1	0	0	0	2 stream crossings, 1 ditch relief culvert
150	4	12	0	0	4	9	2	1	0	12 stream crossings, 4 ditch relief culverts
151	0	15	1	1	9	8	0	0	0	13 stream crossings, 4 ditch relief culverts
154	2	17	1	0	6	10	3	1	0	13 stream crossings, 6 ditch relief culverts, 1 spring
154A	2	2	0	0	2	2	0	0	0	4 stream crossings
1577-130	1	0	1	0	0	0	1	1	0	1 stream crossing, 1 ditch relief culvert
1577-130 Spur 1	3	1	0	0	4	0	0	0	0	1 stream crossing, 2 ditch relief culverts, 1 landslide
2308-180	0	3	1	0	4	0	0	0	0	2 ditch relief culverts, 1 stream crossing, 1 landslide
3577	1	8	2	0	3	2	3	3	0	9 stream crossings, 2 ditch relief culverts
3577 Spur 1A	2	2	1	0	2	2	1	0	0	2 landslides, 2 gullies, 1 ditch relief culvert
3577-130	4	2	0	0	2	3	0	1	0	3 stream crossings, 3 landslides
3577-130 Spur 1	10	0	0	0	4	4	0	1	1	9 stream crossings, 1 ditch relief culvert

Appendix 3c. Treatment priority (Treatment Immediacy) and potential episodic sediment source volumes for inventoried USFS roads in the Indigo Creek Watershed, Biscuit Fire Area (PRC/PWA, 2004)

Road Name (see map)	Treatment Immediacy (H, HM, M, ML, L) ¹				Estimated volume of sites (potential sediment delivery volume) ²					Type of sites
	H;HM	M;ML	L	NO	S	M	L	XL	XXL	
3577-130 Spur 2	4	1	0	0	1	2	0	2	0	3 stream crossings, 1 landslide, 1 gully
440	5	11	0	0	6	10	0	0	0	10 stream crossings, 6 ditch relief culvert
451	0	3	2	0	1	4	0	0	0	4 stream crossings, 1 landslide
480	0	0	1	0	1	0	0	0	0	1 stream crossing
510 Maintained	1	1	1	0	2	0	1	0	0	2 landslides, 1 stream crossing
510 Abandoned	0	4	8	1	8	5	0	0	0	7 stream crossings, 3 springs, 2 gullies, 1 landslide
511	0	1	4	0	3	2	0	0	0	4 stream crossings, 1 spring
761	0	1	13	2	11	5	0	0	0	16 stream crossings
761A	0	0	1	0	1	0	0	0	0	1 stream crossing
761B	0	0	1	0	0	1	0	0	0	1 stream crossing
761C	1	1	2	0	0	4	0	0	0	3 stream crossings, 1 landslide
761D	3	2	9	1	13	2	0	0	0	15 stream crossings
Totals	52	122	62	5	108	100	21	11	1	

¹ Treatment priority: H = High; HM = High-Moderate; M = Moderate; ML = Moderate-Low; L = Low; NO = No treat.

² Volume size classes (cubic yards): Small (S) = 0-100; Medium (M) = 100-500; Large (L) = 500-1,000; XL = 1,000-5,000; XXL = >5,000.

Appendix 3d. Treatment priority (Treatment Immediacy) and potential episodic sediment source volumes for inventoried USFS roads in the Lawson Creek Watershed, Biscuit Fire Area (PRC/PWA, 2004)

Road Name (see map)	Treatment Immediacy (H, HM, M, ML, L) ¹				Estimated volume of sites (potential sediment delivery volume) ²					Type of sites
	H;HM	M;ML	L	NO	S	M	L	XL	XXL	
310	23	24	8	0	36	14	3	2	0	45 stream crossings, 5 gullies, 4 landslides, 1 ditch relief culvert
3680	10	4	2	0	13	2	1	0	0	12 stream crossings, 2 landslides, 2 ditch relief culverts
3680 Spur C	9	1	0	0	8	2	0	0	0	7 stream crossings, 2 landslides, 1 gully
3680 Spur C-1	1	2	0	0	3	0	0	0	0	1 landslide, 1 gully, 1 stream crossing
3680 Spur C-2	2	3	1	0	3	2	1	0	0	4 stream crossings, 1 landslide, 1 gully
3680 Spur C-3	1	0	0	0	0	0	1	0	0	1 stream crossing
Totals	46	34	11	0	63	20	6	2	0	

¹ Treatment priority: H = High; HM = High-Moderate; M = Moderate; ML = Moderate-Low; L = Low; No = No treat.

² Volume size classes (cubic yards): Small (S) = 0-100; Medium (M) = 100-500; Large (L) = 500-1,000; XL = 1,000-5,000; XXL = >5,000.

Appendix 3e. Treatment priority (Treatment Immediacy) and potential episodic sediment source volumes for inventoried USFS roads in the Pistol Creek Watershed, Biscuit Fire Area (PRC/PWA, 2004)

Road Name (see map)	Treatment Immediacy (H, HM, M, ML, L) ¹				Estimated volume of sites (potential sediment delivery volume) ²					Type of sites
	H;HM	M;ML	L	NO	S	M	L	XL	XXL	
3680-360	6	11	0	0	8	8	1	0	0	16 stream crossings, 1 gully
3680-360- JF	5	4	1	0	7	1	2	0	0	7 stream crossings, 3 gullies
Totals	11	15	1	0	15	9	3	0	0	

¹ Treatment priority: H = High; HM = High-Moderate; M = Moderate; ML = Moderate-Low; L = Low; NO = No treat.
² Volume size classes (cubic yards): Small (S) = 0-100; Medium (M) = 100-500; Large (L) = 500-1,000; XL = 1,000-5,000; XXL = >5,000.

Appendix 3f. Treatment priority (Treatment Immediacy) and potential episodic sediment source volumes for inventoried USFS roads in the Silver Creek Watershed, Biscuit Fire Area (PRC/PWA, 2004)

Road Name (see map)	Treatment Immediacy (H, HM, M, ML, L) ¹				Estimated volume of sites (potential sediment delivery volume) ²					Type of sites
	H;HM	M;ML	L	NO	S	M	L	XL	XXL	
050	3	8	2	1	10	4	0	0	0	10 stream crossings, 3 gullies, 1 ditch relief culvert
065	0	1	0	0	0	1	0	0	0	1 stream crossing
090	1	9	11	1	17	5	0	0	0	10 stream crossings, 6 gullies, 4 landslides 1 ditch relief culvert, 1 spring
090A	0	1	0	0	1	0	0	0	0	1 gully
090B	0	0	0	1	1	0	0	0	0	1 stream crossing
091	0	3	11	3	9	6	2	0	0	12 stream crossings, 2 landslides, 2 ditch relief culverts, 1 spring
361	0	4	2	0	6	0	0	0	0	6 stream crossings
665	0	2	2	1	5	0	0	0	0	2 stream crossings, 2 gullies, 1 spring
Totals	4	28	28	7	49	16	2	0	0	

¹ Treatment priority: H = High; HM = High-Moderate; M = Moderate; ML = Moderate-Low; L = Low; NO = No treat.

² Volume size classes (cubic yards): Small (S) = 0-100; Medium (M) = 100-500; Large (L) = 500-1,000; XL = 1,000-5,000; XXL = >5,000.

Appendices 4a - 4f

Recommended treatments along all inventoried roads in the Biscuit Fire area.

Separated by watershed, these tables list the site specific treatments for all inventoried sites recommended for erosion prevention work in the Biscuit Fire area. Recommended erosion prevention work includes roads that have future sediment delivery plus recommended road surface drainage improvements.

Appendix 4a. Proposed treatments for erosion prevention and erosion control for inventoried USFS roads in the Chetco River Watershed, Biscuit Fire Area (PRC/PWA, 2004)										
Proposed Treatment	1376	1376 Spur 100	1909	1909 Spur 1	1909-050	1909-200	1909-200 Spur 1	1909-200 Spur 2	1909-200 Spur 2B	Totals
Install CMP	2	0	1	0	0	0	0	0	2	5
Replace CMP	69	0	11	0	5	2	0	2	0	89
Construct Armored Fill	0	0	0	0	0	0	0	0	2	2
Install DRC	216	0	0	0	0	2	0	0	0	218
Construct Critical Dip	100	0	17	0	7	3	0	2	0	129
Construct Rolling Dip	220	0	52	2	25	47	0	21	0	367
Construct Cross Road Drain	0	8	5	5	0	0	0	0	29	47
Add Flared Inlet	14	0	1	0	0	0	0	0	0	15
Clean CMP Inlet	1	0	0	0	0	0	0	0	0	1
Outslope Road	(4) 2,550'	0	(8) 1,625'	(3) 1,100'	(2) 750'	(5) 6,600'	(1) 120'	(2) 3,150'	0	(25) 15,895'
Excavate and Remove Road Fill ¹	5	0	0	1	1	1	1	0	0	9
Number of Proposed Treatments	631	8	90	11	40	60	2	27	33	

¹ Unstable road fill removed from stream crossings and potential landslides. All removed material will be stored in a safe and stable spoil area.

Appendix 4b. Proposed treatments for erosion prevention and erosion control for inventoried USFS roads in the Illinois River/ Josephine Creek Watershed, Biscuit Fire Area (PRC/PWA, 2004)					
Proposed Treatments	092	092A	092B	4103	Totals
Replace CMP	0	0	0	64	64
Construct Armored Fill	6	0	0	0	6
Install DRC	0	0	2	144	146
Construct Critical Dip	8	0	2	46	56
Construct Rolling Dip	18	2	6	73	99
Construct Cross Road Drain	0	0	12	17	29
Construct sediment basin	1	0	0	3	4
Add Flared inlet	0	0	0	9	9
Clean CMP Inlet	0	0	0	1	1
Outslope Road	(3) 790'	0	(2) 300'	(8) 3,590'	(21) 8,565'
Excavate and Remove Road Fill ¹	1	0	0	2	3
Realign Road	2	0	1	0	3
Number of Proposed Treatments	40	2	13	370	
¹ Unstable road fill removed from stream crossings and potential landslides. All removed material will be stored in a safe and stable spoil area.					

Appendix 4c. Proposed treatments for erosion prevention and erosion control for inventoried USFS roads in the Indigo Creek Watershed, Biscuit Fire Area (PRC/PWA, 2004)																	
Proposed Treatments	052	055	071A	150	151	154	154A	1577-130	1577-130 Spur 1	2308-180	3577	3577 Spur 1A	3577-130	3577-130 Spur 1	3577-130 Spur 2	440	Totals
Replace CMP	4	2	0	0	0	0	1	0	0	0	0	0	0	1	0	7	15
Install CMP	4	13	1	7	3	7	2	0	1	0	9	0	1	1	0	4	53
Install DRC	2	20	0	2	2	5	0	4	1	0	0	2	0	0	0	0	38
Construct Critical Dip	7	18	1	10	6	9	2	1	0	1	6	0	2	7	2	10	82
Construct Rolling Dip	71	70	2	49	45	64	23	5	0	12	24	6	18	38	12	30	469
Add Flared Inlet	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Clean CMP Inlet	1	4	0	2	5	3	2	0	3	0	0	0	0	0	0	0	20
Excavate and Remove Road Fill ¹	2	1	0	0	0	0	0	0	0	1	0	2	3	1	1	0	11
Clean Ditch	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Number of Proposed Treatments	91	133	4	70	61	89	30	10	5	14	39	10	24	48	15	51	

¹ Unstable road fill removed from stream crossings and potential landslides. All removed material will be stored in a safe and stable spoil area.

Appendix 4c. Proposed treatments for erosion prevention and erosion control for inventoried USFS roads in the Indigo Creek Watershed, Biscuit Fire Area (PRC/PWA, 2004)											
Proposed Treatments	451	480	510 Maintained	510 Abandoned	511	761	761A	761B	761C	761D	Totals
Replace cmp	1	0	0	0	1	1	0	0	0	2	5
Install DRC	0	0	0	0	9	1	0	0	0	0	10
Construct Critical Dip	3	1	0	0	3	12	1	1	1	10	32
Construct Rolling Dip	12	3	2	0	9	12	1	0	2	5	46
Construct Cross Road Drain	0	0	0	99	0	0	0	0	0	0	99
Add Flared Inlet	0	0	0	0	1	0	0	0	0	0	1
Clean CMP Inlet	1	0	0	0	0	1	0	1	0	1	4
Outslope Road	0	0	0	0	(1) 500'	0	0	0	0	0	(1) 500'
Excavate and Remove Road Fill ¹	1	0	2	9	0	0	0	0	0	0	12
Number of proposed treatments	18	4	4	108	24	27	2	2	3	18	

¹ Unstable road fill removed from stream crossings and potential landslides. All removed material will be stored in a safe and stable spoil area.

Appendix 4d. Proposed treatments for erosion prevention and erosion control for inventoried USFS roads in the Lawson Creek Watershed, Biscuit Fire Area (PRC/PWA, 2004)																	
Proposed Treatments	310	3318 Spur 1	3318-310 Spur J3	3318-310 Spur J-1	3318-310 Spur J-1A	3318-310 Spur J-1B	3318-310 Spur J-1C	3318-310 Spur J-1D	3318-310 Spur J-1E	3318-310 Spur J-1F	3318-310 Spur J-2	3680	3680 Spur C	3680 Spur C-1	3680 Spur C-2	3680 Spur C-3	Totals
Install cmp	4	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	8
Replace cmp	33	0	0	0	0	0	0	0	0	0	0	11	6	1	1	0	52
Construct Critical Dip	34	0	0	1	0	0	0	0	0	0	0	9	7	1	2	1	55
Construct Rolling Dip	208	0	0	0	0	0	0	0	0	0	0	83	46	6	24	2	369
Construct Cross Road Drains	0	17	0	75	6	2	16	13	5	42	0	0	0	0	0	0	176
Outslope Road	0	0	0	(1) 1,410'	0	(1) 100'	0	(1) 675'	0	(4) 1,400'	(1) 300'	0	0	0	0	0	(8) 3,885'
Clean CMP Inlet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Excavate and Remove Road Fill ¹	0	7	0	3	1	0	1	0	1	0	1	0	2	1	1	0	18
Number of Proposed Treatments	279	21	0	80	7	3	17	14	6	46	2	104	62	9	29	4	

¹ Unstable road fill removed from stream crossings and potential landslides. All removed material will be stored in a safe and stable spoil area.

Appendix 4e. Proposed treatments for erosion prevention and erosion control for inventoried USFS roads in the Pistol River Watershed, Biscuit Fire Area (PRC/PWA, 2004)			
Proposed Treatments	3680-360	3680-360-JF	Totals
Install cmp	0	3	3
Replace cmp	15	4	19
Install DRC	42	0	42
Construct Critical Dip	14	5	19
Construct Rolling Dip	25	6	31
Outslope road	(11) 10,070'	(2) 200'	(13) 10,270'
Number of Proposed Treatments	107	20	
¹ Unstable road fill removed from stream crossings and potential landslides. All removed material will be stored in a safe and stable spoil area.			

Appendix 4f. Proposed treatments for erosion prevention and erosion control for inventoried USFS roads in the Silver Creek Watershed, Biscuit Fire Area (PRC/PWA, 2004)									
Proposed Treatments	050	065	090	090A	090B	091	361	665	Totals
Install cmp	1	0	5	0	0	0	0	1	7
Replace cmp	6	1	2	0	0	2	4	0	15
Install DRC	0	0	1	0	0	2	2	1	6
Construct Armored Fill	0	0	2	0	0	0	0	0	2
Construct Critical Dip	3	1	3	0	0	1	3	1	12
Construct Rolling Dip	22	1	45	0	0	26	10	21	125
Construct Cross Road Drain	0	0	0	8	0	0	0	0	8
Clean CMP inlet	0	0	0	0	0	4	0	0	4
Outslope Road	0	0	(2) 1,600'	0	0	(1) 220'	0	0	(3) 1,820
Excavate and Remove Road Fill ¹	0	0	4	0	0	2	0	0	6
Number of Proposed Treatments	32	3	64	8	0	38	19	24	

¹ Unstable road fill removed from stream crossings and potential landslides. All removed material will be stored in a safe and stable spoil area.

Appendix 5

Preliminary (Map-Based) Restoration Cost Estimate for Road-Related Erosion Control and Erosion Prevention in the Biscuit Fire Area, Southern Oregon

This preliminary cost estimate was derived prior to the field reconnaissance inventory and was based on the 503 miles of forest roads contained on USFS maps and digital map data

**Appendix 5. Preliminary, Phase 1 Restoration Cost Estimate for
Road-Related Erosion Control and Erosion Prevention
in the Biscuit Fire Area, Southern Oregon**

Prior to the conduct of the reconnaissance road filed inventory, a preliminary restoration cost estimate was prepared for roads within the Biscuit Fire area. This involved using only the USFS mapped roads, as depicted on hard copy road maps and digital map data, which have since been determined to be approximately 30% under-reported.

Methods

The development of a preliminary, office based estimate for upgrading or “storm-proofing” approximately 503 miles of roads within the Biscuit Fire area of Southern Oregon involved several steps. First, GIS data, provided by the USFS was analyzed to determine the total road miles, by level of use and surfacing standards, within the Biscuit Fire area. The roads fell into 5 classes of road: asphalt or bituminous surfaced roads (49 miles), crushed aggregate or gravel roads (263 miles), improved native roads (3 miles), native roads (137 miles) and miscellaneous low standard, possibly abandoned roads (51 miles).

The roads were then segmented ocularly into 3 classes of road based on hillslope position: ridge roads (294 miles), midslope roads (135 miles) and streamside roads (74 miles). These road segments were then mapped in GIS to determine the total miles of road by the combined hillslope position and road surfacing categories (Table 1).

Based on the total road miles in Table 1, we then reviewed published costs for conducting upland road assessments, as well as costs to implement large scale road upgrading projects in order to assign approximate costs to accomplish each element (Weaver and Hagens, 1994; Weaver and Hagens, 1996; Weaver and Hagens, 1999; Weaver and Hagens, in press; PWA, 2004).

Table 1. Road miles by type of surface and hillslope position, Biscuit Fire area.				
Road Type	Ridge Roads	Midslope Roads	Streamside Roads	Totals
Asphalt/Bituminous	30	6	13	49
Aggregate/Gravel	148	89	26	263
Improved Native	2	1	0	3
Native	90	27	20	137
Other Low Use	24	12	15	51
Totals:	294	135	74	503

Conducting comprehensive upland road assessments involves identifying all existing and potential sediment delivery sites along the road system, and prescribing appropriate long term prescriptions or treatments to either lower the risk of the erosion occurring or prevent future erosion and sediment delivery at each identified site. A properly conducted upland road assessment will also include prioritizing each identified site for treatment, as well as developing an estimate of all costs for heavy equipment, labor, materials and supervision to complete each treatment.

Different costs for conducting a comprehensive road assessment and erosion prevention planning project were assigned to the roads depending on their hillslope position. For the ridge roads, we assigned a range of \$600 to \$800 per mile of road; for midslope roads, we assigned a range of \$1000 to \$1300 per mile; and for streamside roads a range of \$1000 to \$1300 per mile. We estimate comprehensive road assessments for the 503 miles of road will cost between \$477,000 and \$586,000 (Table 2).

Developing an office based cost estimate to upgrade and treat 503 miles of roads throughout wildland watersheds is far more difficult. We have assumed most roads would be retained for future land use and resource management, but are conscience some routes would likely be good candidates for proper road closure or decommissioning. This should not pose a problem since, generally speaking, properly decommissioning a road should cost less than upgrading a road, due largely to the cost savings in culvert, rock and other materials. Considerable variability exists in wildland settings, where the size and frequency of stream crossings and the frequency and/or the extent of sidecast road construction, can generate very dramatic changes in the unit cost to treat a given segment of road.

For these reasons we have assigned a range of costs to treat the various roads based on both their current surfacing status (i.e. paved, rocked, native, etc.), as well as the hillslope position (i.e. mostly ridge top, midslope or streamside). We have assumed that if a site is on a paved or rocked road, the treatment would involve re-paving or re-rocking the disturbed portion of the road. We have estimated the range of costs based on typical heavy equipment and labor rates to perform similar road restoration and road maintenance activities in the Klamath Mountain region of northern California and southern Oregon. For example, a medium sized excavator would cost \$125 to \$145 per hour, a D5 or D6 dozer would cost \$100 to \$125 per hour, a water truck would cost \$90 to \$110 per hour, etc. Costs for materials such as culverts, road and rip-rap sized rock, asphalt, seed and mulch are included in the cost estimate.

A properly upgraded road displays several characteristics. These include:

- 1) sizing and installing all stream crossings to accommodate the 100-year storm discharge with considerations for sediment and organic debris which will be in transport;
- 2) minimizing the potential for future landsliding and fill failures through the practice of excavating or stabilizing sidecast fill material along the roads;

3) minimizing the length of road which is “hydrologically connected” to the stream network by modifying road drainage shapes (i.e. outsloping roads with and without an inboard ditch, insloping, crowning, etc.), and utilizing the proper number and spacing of road drainage structures (i.e. ditch relief culverts, berm drains, rolling dips draining the road only or the road

and ditch, cross road drains and waterbars). Current standards provided by the U.S. EPA and the North Coast Regional Water Quality Control Board for several river basins with recently completed TMDL implementation plans indicate from 80% to 95% of the road system, or more, should be disconnected from the stream network; and

4) providing for fish passage at all stream crossing sites on fish bearing streams.

To upgrade or storm-proof the 294 miles of ridge roads in the Biscuit Fire area, we have estimated a range of costs from \$10,000 to \$22,000 per mile of road. To upgrade and treat the 135 miles of midslope roads, we estimate the costs will range from a low of \$25,000 to a high of \$47,000 per mile of road. For the 74 miles of streamside roads, treatment costs are expected to range from \$35,000 to \$77,000 per mile of road. We estimate costs to upgrade the 503 miles of road in the Biscuit Fire area will range from a low of \$13,000,000 to a high of \$19,000,000 (Table 2).

Table 2. Office based road restoration cost estimate, Biscuit Fire area.		
Cost Category	Lower Cost Estimate	Upper Cost Estimate
Conduct Prioritized Road Assessment	\$477,000.	\$586,000.
Perform Road Restoration (primarily road upgrading)	\$13,000,000.	\$19,000,000.
Road Assessment plus Road Restoration	\$13,477,000.	\$19,586,000.
USFS Project Management (+/- 25% for NEPA, contracting, coordination with contractors, monitoring, etc.)	\$3,370,000.	\$4,900,000.
Sub Total	\$16,847,000.	\$24,486,000.
Contractors, Non-Profit Overhead (12%)	\$2,021,000.	\$2,938,000.
Total Budget	\$18,868,000.	\$27,424,000.

We have budgeted time at 25% of the total road assessment and road restoration costs for the USFS to administer a road restoration program. The costs range from a low of \$3,370,000 to a

high of \$4,900,000 (Table 2). We envision these costs to cover NEPA and other environmental reviews, contracting, coordination with contractors, monitoring, etc. Finally, we have included an estimate for general overhead at 12% for consultants, contractors and non-profit organizations who would likely perform or oversee the majority of the road assessment and road implementation work.

To develop both a prioritized erosion control and erosion prevention plan, as well as implement the plan over the next 10 to 15 years, our office based estimate suggests between \$18,868,000 and \$27,424,000 are needed.

References

Pacific Watershed Associates, 1994, *Handbook for forest and ranch roads*. Prepared for the Mendocino County Resource Conservation District in cooperation with the California Department of Forestry and the U.S. Soil Conservation Service. 163 pages.

Pacific Watershed Associates, 2004, *Upslope assessment and restoration practices*. Chapter 10, IN: California Salmonid Stream Habitat Restoration Manual, California Department of Fish and Game, Sacramento, CA, 90 pages + appendices.

Weaver, W.E. and D.K. Hagans, 1996, *Sediment treatments and road restoration: protecting and restoring watersheds from sediment-related impacts*, chapter 4 In: Healing the Watershed - A Guide to the Restoration of Watersheds and Native Fish in the West. The Pacific Rivers Council, Eugene, Oregon. pages 109-140.

Weaver, W.E. and D.K. Hagans, 1999, *Storm-proofing forest roads*. In: Proceedings of the International Mountain Logging and 10th Annual Pacific Northwest Skyline Symposium, Oregon State University, Department of Forest Engineering and International Union of Forest Research Organizations, J. Sessions and W. Chung, eds., 3/28 - 4/1/99, Corvallis, Oregon. pages 230-245

Weaver, W.E. and D.K. Hagans, 2004, *Road upgrading, decommissioning and maintenance – estimating costs on small and large scales*. In: Proceedings, NMFS Salmonid Habitat Restoration Cost Workshop. Portland, Oregon, November 14-16, 2000.